The Magazine Of
The Institution Of Engineers, Singapore
May 2015 MCI (P) 074/03/2015

Celebrating 50 Years of Engineering Excellence

www.ies.org.sg

THE SINGAPORE ENGINEER

COVER STORY:

MECHANICAL & ELECTRICAL ENGINEERING

Philips Lumileds Singapore Plant

FEATURES:

Transportation Engineering • Power Generation • Electrical & Electronics Engineering

POWER-GEN ASIA

As part of ASEAN **POWER WEEK**

Conference & Exhibition

1 – 3 September 2015
IMPACT Exhibition & Convention Centre
Bangkok, Thailand

INVESTING IN A **SUSTAINABLE TOMORROW**

www.powergenasia.com

MAKE PLANS TO BE PART OF ASIA'S PREMIER POWER EVENT

PRELIMINARY EVENT GUIDE NOW AVAILABLE

POWER-GEN Asia, as part of ASEAN Power Week alongside Renewable Energy World Asia and the POWER-GEN Asia Financial Forum, has become the leading force in delivering a platform for the power industry to meet, share information on the challenges facing the power industry and discuss solutions for advancing Asia's energy future.

We invite you to join us at POWER-GEN Asia to meet and network with over 7,500 attendees from more than 65 countries across South East Asia and around the world.

SAVE OVER 20% AS AN IES MEMBER

Register yourself and your colleagues as conference delegates and benefit from the IES Member Rate, plus free entry to the exhibition. Register using the Supporting Association registration type and select IES. There is no better place to meet the key decision makers in the power generation industry.

REGISTER FOR ONE EVENT AND GAIN ACCESS TO ALL 3 CO-LOCATED EVENTS
REGISTER NOW AT WWW.POWERGENASIA.COM

www.**powergenasia**.com

Owned and Produced by: PennWell

Presented by: PEi Power Engineering, Renewable Energy World.com

Supported by: TCEB, Department of Alternative Energy Development and Efficiency Ministry of Energy, DNW

Co-located events: Renewable Energy World Conference & Expo – Asia –, POWER-GEN Asia Financial Forum

CONTENTS

Celebrating 50 Years of Engineering Excellence

Founded in 1966

FEATURES

10 MECHANICAL & ELECTRICAL ENGINEERING: COVER STORY:
Philips Lumileds Singapore Plant
Initiatives such as the optimisation of the chiller plant contributed to the project winning the Green Mark Platinum Award under the Existing Buildings category.

14 INFORMATION TECHNOLOGY:
Transforming infrastructure development and management
The increasing sophistication of software will change the way in which projects are implemented and operated.

16 TRANSPORTATION ENGINEERING:
Connecting the last mile of the journey
The Land Transport Authority (LTA) implements programmes for the benefit of all commuters.

23 SUSTAINABILITY:
Efficiency - the key to meeting global energy demand
It is necessary to adopt efficient methods of energy production and reduce energy wastage.

24 POWER GENERATION:
Gas turbine air filter system optimisation
The performance and reliability of the equipment will be improved.

30 POWER GENERATION:
Gas turbine inlet air fogging for humid environments
The technology offers improved performance and economic benefits.

38 ELECTRICAL & ELECTRONICS ENGINEERING:
Understanding Electromagnetic Interference and Electromagnetic Compatibility
This will help engineers in product design.

REGULAR SECTIONS

02 MESSAGE

04 IES UPDATE

42 EVENTS

44 NEWS

Chief Editor
T Bhaskaran
t_b_n8@yahoo.com

CEO
Angie Ng
angie@iesnet.org.sg

Publications Manager
Desmond Teo
desmond@iesnet.org.sg

Publications Executive
Ho Wei Ting
ho.wt@iesnet.org.sg

Media Consultants
Roland Ang
roland@iesnet.org.sg

Desmond Chander
desmond@shamrockcraine.com

Published by
The Institution of Engineers, Singapore
70 Bukit Tinggi Road
Singapore 289758
Tel: 6469 5000 Fax: 6467 1108

Cover designed by Stephanie Kwan
Cover image by
Barghest Building Performance

The Singapore Engineer is published monthly by The Institution of Engineers, Singapore (IES). The publication is distributed free-of-charge to IES members and affiliates. Views expressed in this publication do not necessarily reflect those of the Editor or IES. All rights reserved. No part of this magazine shall be reproduced, mechanically or electronically, without the prior consent of IES. Whilst every care is taken to ensure accuracy of the content at press time, IES will not be liable for any discrepancies. Unsolicited contributions are welcome but their inclusion in the magazine is at the discretion of the Editor.

Design & layout by 2EZ Asia Pte Ltd
Printed in Singapore

Message from the Deputy President, IES and Chairman, IES Chemical and Process Engineering Technical Committee

In Singapore, solar energy is already below grid parity, making the pay back of solar PV systems within 8 to 10 years very viable, as all solar modules are guaranteed to last 25 years. In fact, the returns for an investment in a solar PV system is better than returns obtained from fixed deposits offered by banks in Singapore.

It is therefore critical that emerging economies look at adopting and introducing policies to attract investments into proven and tested clean energies like solar and wind technologies to ensure the successful deployment of these much needed clean technologies to fuel their economic growth and not to rely on coal and low grade fuel oils which are cheaper and are low-end technologies which many of these economies (including China and India.) are still using.

Conditions causing climate change are irreversible and once the world breaches the 2° C tipping point or the 460 parts per million (ppm) of carbon dioxide level in the atmosphere, extreme weather and climate conditions worldwide will become worse, increasing exponentially the melting of ice caps in both the North and South poles and causing a rise in sea levels of more than 2 m before the end of this century, causing many islands to disappear (eg Maldives and a number of South Pacific Islands) and many large urban cities to be submerged, eg New York, Bangkok, Jakarta, Manila etc, where millions of people will be displaced. Worse still, weather like extreme rain fall (causing floods and mudslides) and many months of drought, super-typhoons, hurricanes and cyclones will increase in occurrence, which will destroy crops and properties, kill thousands of people and create 'hell on earth'.

From meteorological science and powerful satellites and computers, we can predict these extreme weather changes, most of the time, and can protect ourselves and our environment as well as adapt to these extreme conditions. We can also make our cities more resilient to floods and droughts and to super-typhoons and storms. All these innovations and adaptation requires engineering solutions, eg building dykes and seawalls to protect against sea water rise, widening and deepening rivers and canals to accept greater volumes of water from heavy rains and extreme typhoons, desalinating sea water and recycling used water to fight dry conditions using the latest in membrane technologies and systems, reinforcing hills and slopes to prevent landslides and creating drainage in the hill slopes to prevent mudslides, and many more of these engineering innovations and solutions required of engineers.

All these issues and solutions will be presented, discussed and debated by world renowned engineers and scientists at the World Engineers Summit on Climate Change (WES) 2015, which will be held from 21 to 24 July 2015 at the Suntec Singapore Convention and Exhibition Centre. At this conference and exhibition, you will learn about climate change and the many solutions and innovations many cities are already deploying to protect their cities against climate change and its effects.

For more information on WES 2105, which is organised by IES, please log on to www.wes-ies.org.

Come join us and learn about how you can participate and be proactive in adapting to climate change and to network with engineers, practitioners and scientists who have most of the answers to the questions that you may have about whether Singapore and regional countries have done enough to make themselves more resilient to climate change.

Er. Edwin Khew
Deputy President, IES and Chairman, IES Chemical and Process Engineering Technical Committee

IES Council Members 2015 / 2016

President
Er. Chong Kee Sen

Deputy President
Er. Edwin Khew

Honorary Secretary
Dr Boh Jaw Woei

Honorary Treasurer
Er. Koh Beng Thong

Vice Presidents
Er. Chan Ewe Jin
Er. Ng Say Cheong
Dr Richard Kwok
Er. Seow Kang Seng
Prof Yeoh Lean Weng

Immediate Past President
Prof Chou Siaw Kiang

Past Presidents
Er. Ho Siong Hin
Er. Dr Lee Bee Wah

Assistant Honorary Secretary
Mr Joseph William Eades

Council Members
Mr Dalson Chung
Prof Er Meng Joo
Dr Goh Yang Miang
Ms Jasmine Foo
A/Prof Lee Poh Seng
Mr David So
Er. Joseph Goh
Mr Mervyn Sirisena
Mr Tan Sim Chuan
Er. Teo Chor Kok
Er. Joseph Toh
Er. Alfred Wong
Dr Zhou Yi

Honorary Council Members
Er. Ong Ser Huan
Er. Tan Seng Chuan

Engineering: Transforming Singapore 50 Years and Beyond

In line with the SG50 celebrations, IES is organising a photo competition to celebrate the achievements and contributions of engineering while envisioning the future.

Calling out to all photo enthusiasts to capture the essence of engineering in our photo competition.

Closing date for entries : 15 June 2015
Announcement of results: Aug/Sep 2015

2 GRAND PRIZES

1) Single shot category:

$1500

2) Story Board category:

$2000

6 HONORARY MENTION

3 in each of the 2 categories

IES PHOTOGRAPHY COMPETITION 2015

Organised by:

Supported by:

Eligibility*:

The competition is open to all photography enthusiasts (including professionals & amateurs) residing in Singapore.

*** Terms and conditions apply.**

Show us:

How has engineering transformed the way we live, work and play?

Why is engineering important to our society?

Who are the beneficiaries of engineering feats?

What does engineering mean to you?

Where would engineering lead us to in the future?

When have you been inspired by engineering?

For registration and more information, please visit our website at: http://www.ies.org.sg/PhotoCompetition

For enquiries, please email desmond@iesnet.org.sg

Photo credits: "Capture Greenery Moment" by Zhuo Fenghui, Singapore

21-24 JULY 2015 | SUNTEC SINGAPORE CONVENTION & EXHIBITION CENTRE
WORLD ENGINEERS SUMMIT
CLIMATE CHANGE

Engineers to address major global challenge and present solutions

Triggered by rapid urbanisation and industrialisation activities, global warming is unleashing undesirable effects across the globe, increasing average temperature, raising seawater levels, causing unpredictable weather patterns, and destroying food crops, properties and lives. No country is immune to climate change and the variability it brings to the weather. There is a mounting necessity to place sustainability at the core of urban and industrial development.

With their intellectual and problem-solving capacities, engineers are best placed to lead the transition to a sustainable future, by analysing problems and developing cost-effective technological solutions as well as bringing knowledge about the problem of climate change and the urgency in resolving it to the community-at-large and working with other stakeholders to bring about real progress.

In recognition of the above and following on from the success of the inaugural event in 2013, the Institution of Engineers, Singapore (IES) is organising the World Engineers Summit on Climate Change (WES) 2015, to provide a platform for the global community to exchange insights and ideas to address the effects of climate change.

WES 2015 will be held from 21 to 24 July 2015 at the Suntec Singapore Convention and Exhibition Centre.

The event, which will address the theme 'Sustainable Urban Development for Global Climate Resilience', will bring together engineers from multiple disciplines, urban planning specialists, energy specialists, environmental and water specialists, academia, financiers, policy makers, researchers and business leaders of corporations from across industries, worldwide, for an active dialogue on sustainable and technology-led solutions for a world facing the real threat of Climate Change.

GUESTS-OF-HONOUR

OPENING CEREMONY

Mr Teo Chee Hean, Deputy Prime Minister, Coordinating Minister for National Security and Minister for Home Affairs, Singapore

WES INDUSTRY ROUNDTABLE ON CLIMATE CHANGE AND BUSINESSES - CHALLENGES AND OPPORTUNITIES (BY INVITATION ONLY)

Dr Vivian Balakrishnan, Minister for Environment & Water Resources, Singapore

WES GALA DINNER & AWARDS NIGHT

Mr Chan Chun Sing, Secretary-General, the National Trades Union Congress, Singapore

NATIONAL ENGINEERS DAY PRIZE PRESENTATION

Mr Heng Swee Keat, Minister for Education, Singapore

SUMMIT HIGHLIGHTS

The WES Industry Roundtable on Climate Change will be held on 21 July.

The Plenary Keynote Speakers are Dr Bindu N Lohani, Vice-President, Knowledge Management & Sustainable Development, Asian Development Bank, Philippines; Mr Tan Gee Paw, Chairman, Public Utilities Board; and Mr Philippe Joubert, Senior Advisor and Special Envoy for Energy and Climate, World Business Council for Sustainable Development and Executive Chairman for Global Electricity Initiative, France. WES 2015 will feature presentations within four tracks on 22 and 23 July.

The Panel Session Chair is Prof Tommy Koh, Ambassador-at-Large, Ministry of Foreign Affairs, Singapore.

TRACK 1 - CLEAN ENVIRONMENT & WATER RESOURCES

Track Opening Keynote Speaker - Mrs Lim Hwee Hua, Executive Director, Tembusu Partners Pte Ltd, Singapore

Session A - Clean Environment

Track Keynote Speaker - Dr Arab Hoballah, Chief of the Sustainable Consumption and Production Branch, Division of Technology, Industry and Economics of United Nations Environment Programme, Kenya

Session B – Water Resources

Track Keynote Speaker - Prof Roger Falconer, President, International Association of Hydro-Environment Engineering and Research, United Kingdom

Session C – Recycling and Waste Management

Track Keynote Speaker - Mr David Newman, President, International Solid Waste Association, Austria

21-24 JULY 2015 | SUNTEC SINGAPORE CONVENTION & EXHIBITION CENTRE

WORLD ENGINEERS SUMMIT
CLIMATE CHANGE

TRACK 2 - SUSTAINABLE DEVELOPMENT & INFRASTRUCTURE

Track Opening Keynote Speaker - Mr Lee Yi Shyan, Senior Minister of State, Ministry of Trade and Industry and Ministry of National Development, Singapore

Session A - Sustainable Development

Track Keynote Speaker - Mr Ravinder Singh, President, Singapore Technologies Kinetics Ltd, Singapore

Track Keynote Speaker - Dr Cheong Koon Hean, Chief Executive, Housing & Development Board, Singapore

Session B - Sustainable Infrastructure

Track Keynote Speaker - Dr Yamina Saheb, Scientific and Policy Officer, European Commission, Joint Research Centre, Belgium

Track Keynote Speaker - Mr Antony Sprigg, Chief Executive Officer, Infrastructure Sustainability Council of Australia, Australia

Session C - Smart & Innovative Cities

Track Keynote Speaker - Prof Peter Newman, Professor of Sustainability, Curtin University, Australia

TRACK 3 - SUSTAINABLE ENERGY

Track Opening Keynote Speaker - Mr Teo Ser Luck, Minister of State, Ministry of Trade and Industry and Mayor, North East District, Singapore

Session A - Energy Efficiency in Buildings and Industrial Processes

Track Keynote Speaker - Prof Jim Skea, Vice President, Energy Institute, United Kingdom

Session B - Renewable Energy Systems & Technologies

Track Keynote Speaker - Mr Stephen Selkowitz, Senior Advisor for Building Science and Group Leader, Windows and Envelope Materials Group, Building Technology and Urban Systems Division, Lawrence Berkeley National Laboratory, United States of America

Session C - Energy Modelling & Policy

Track Keynote Speaker - Dr John Keung Kam Yin, Chief Executive Officer, Building and Construction Authority, Singapore

TRACK 4 - RESILIENCE & ADAPTATION AGAINST CLIMATE CHANGE

Track Opening Keynote Speaker - Dr Bindu N Lohani, Vice-President, Knowledge Management & Sustainable Development, Asian Development Bank, Philippines

Session A - Planning : Integrated Urban Planning for Climate Resilient Cities

Track Keynote Speaker - Dr Norman Lowe, President, Chartered Institution of Water and Environmental Management, United Kingdom

Session B - Information : Bridging Climate Science and Engineering Knowledge for Urban Development

Track Keynote Speaker - Dr Steven Wade, Principal Consultant and Head of Scientific Consultancy, Met Office, United Kingdom

Session C - Solutions : Building Climate Resilient Cities

Track Keynote Speaker - Mr Khoo Teng Chye, Executive Director, Centre for Liveable Cities, Singapore

Track Keynote Speaker - Prof Liu Chuang, Professor, Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, China Association for Science and Technology, China

WES 2015 EXPO

Climate change impacts are real. Engineers are seeking better, cleaner and more sustainable solutions.

To be held from 22 to 24 July 2015, WES 2015 Expo will provide a showcase of the latest in green and sustainable engineering solutions to meet market needs as well as research work and innovations for climate change mitigation.

The expo is expected to attract a wide range of visitors including engineers from multiple disciplines; scientists and researchers; consultants; manufacturers, processors, builders and logistics services providers; technology developers and investors; research funding organisations; business leaders; government leaders and non-governmental organisations.

TECHNICAL SITE VISITS

There will be Technical Site Visits on 24 July, to Marina Barrage, HDB Centre of Building Research, Punggol Waterway, Jurong Eco-Garden @ CleanTech Park and Singapore Sports Hub.

WES 2015 PHOTOGRAPHY COMPETITION

The WES 2015 Photography Competition on the theme 'About Climate Change', provides a creative channel to bring attention to, and encourage participation in climate change awareness and mitigation.

WES2015

21-24 JULY 2015 | SUNTEC SINGAPORE CONVENTION & EXHIBITION CENTRE

WORLD ENGINEERS SUMMIT

CLIMATE CHANGE

NATIONAL ENGINEERS DAY 2015

Co-located with WES 2015, National Engineers Day 2015 (NED 2015) will comprise the Energy Innovation Challenge 2015, talks and workshops, and an exhibition.

NED is an annual event organised by IES to celebrate the achievements of engineers, inspire young engineers, and intrigue the young generation in engineering. NED comprises a series of fun and enriching activities demonstrating the ingenuity of engineers and the myriad of possibilities of an engineering career.

As the national institution for engineers, IES is charged with the mission to advance and promote the science, art and profession of engineering. One of the key goals of IES is to nurture future engineering thought leaders, innovators and entrepreneurs, to sustain the economic growth of Singapore and our quality of life.

Since initiating NED in the year 2010, IES has partnered with tertiary institutions, government agencies, engineering organisations and industry experts, to grow it into one of the biggest engineering festivals in Singapore.

Energy Innovation Challenge 2015

The inaugural Energy Innovation Challenge is organised by IES and Science Centre Singapore. The competition provides an opportunity for innovation by students from secondary schools, junior colleges, ITEs, polytechnics and universities to work with professional engineering and business mentors to design or invent a product to solve and demonstrate the use of an alternative source of energy. Schools can field teams of individual or several students in a team to take part in high-intensity events and camps as a run-up to the challenge. Teams will be evaluated on the basis of the end product, the power of team strategy and collaboration, and the determination of students.

The competition will culminate in project displays, final judging, and presentation of awards at NED 2015.

For more information, please contact:
WES 2015 Secretariat
The Institution of Engineers, Singapore (IES)
Tel: 65-64611240 / 65-64695000
Email: wes.ned@iesnet.org.sg
Website: www.WES-IES.org

A track session in progress at WES 2013

An exhibit at the WES 2013 Expo

Join the conversation on Engineering Sustainable Solutions for Climate Change at WES 2015

WORLD ENGINEERS SUMMIT
WES2015 | CLIMATE CHANGE

21-24 JULY 2015
SUNTEC SINGAPORE CONVENTION & EXHIBITION CENTRE SINGAPORE

The World Engineers Summit on Climate Change 2015 is engaging top thought leaders and influencers in engineering and policy to develop innovative solutions to climate change. We are connecting engineers with policy makers, urban planners, specialists in energy, water and the environment, with industry and academia to drive new business opportunities and partnerships.

Join us in the discussion and play your part in solving one of the greatest challenges facing mankind and our planet today.

Complimentary Invitation to the
Lead Up Event of WES on Climate Change 2015

Forum on "Engineers and Sustainable Development"
4 June 2015 Thursday 1800hrs
NTUC Centre Auditorium - One Marina Boulevard

Speakers and Panellists :
Ms Goh Swee Chen, Chairperson, Shell Singapore
Dr Sanjay C Kuttan, Director and Country Manager, Clean Technology Centre, DNV GL-Energy

Moderator :
Mr Constant Van Aerschot, Executive Director
Business Council for Sustainable Development Singapore

Registration : www.WES-IES.org/Forum
Enquiry : WES2015Forum@IESnet.org.sg

Open for registration now!
Free admission to the WES 2015 Expo for trade visitors.

Full Programme WES Sessions, Expo, Welcome Reception, Gala Dinner and Technical Site Visit	S$1,000
Daily Pass WES Sessions and Expo	S$600/per day
Student Pass WES Sessions, Expo and Technical Site Visit	S$400
Technical Site Visit	S$150

Scan the QR code or visit **www.WES-IES.org** for more information on the World Engineers Summit on Climate Change 2015

Sponsors

Gold

jtc · Keppel Offshore & Marine · sembcorp · ST Engineering

Silver

Dredging International ASIA PACIFIC · Jebsen & Jessen · Land Transport Authority · Mitsubishi Electric Changes for the Better · Nanyang Technological University · SIM University

Bronze

BMW · Building and Construction Authority · City Developments Limited · Daikin · DNV·GL · Dragages Singapore · Santarli · SUTD · SPRING singapore

General

ak · BRC Prefab The Art of Reinforcing · Lee Foundation · WAK

Lanyard

Pavilion Energy

Lead Up Event

TriTech

Media Partner

Eco-Business · sph

Organised by

Supported by

Held in

As at 7 May 2015

The next frontier of engineering - opportunities and challenges in dermatology research and patient care

On 10 April 2015, A/Prof Dr Steven Thng, Senior Consultant, Head Pigment Clinic, National Skin Centre (NSC), Singapore, presented a talk to an audience comprising engineers and professionals from various industries and sectors.

In his presentation, Dr Thng reiterated that the role of engineers is a key factor in tackling skin disorders, particularly with respect to their contribution to skin tissue engineering and regenerative medicine (TERM).

Dr Thng graduated from National University of Singapore (NUS) in 1992 and went on to pursue his interest in Humanitarian and Disaster medicine with the Singapore Armed Forces (SAF) from 1992 to 2002. In the 10 years that he was with the Army Medical Services, Dr Thng was frequently deployed in disaster zones as well as countries with civil unrest, providing medical help to the populations in those countries. It was during these deployments that he discovered his interest in dermatology and he went on to be trained as a dermatologist in 2002.

BETC Chairman Dr Ho Teck Tuak giving the welcoming address.

Dr Thng started the pigment clinic in NSC as well as set up the melanocyte culture lab to start his work on cultured melanocytes grafting for vitiligo patients. Currently, Singapore is one of the few countries in the world providing cellular grafting for patients with vitiligo.

At the end of his talk, Dr Thng received a token of appreciation from Dr Ho Teck Tuak, Chairman, Biomedical Engineering Technical Committee (BETC), IES.

Tissue engineering and regenerative medicine

Tissue engineering evolved from the field of biomaterials development. The goal of tissue engineering is to assemble functional constructs that restore, maintain, or improve damaged tissues or whole organs. Artificial skin and cartilage are examples of engineered tissues.

Regenerative medicine is a broad field that includes tissue engineering but also incorporates research on self-healing - where the body uses its own systems, sometimes with help from foreign biological materials, to recreate cells and rebuild tissues and organs. The terms 'tissue engineering' and 'regenerative medicine' have become largely interchangeable, as the field hopes to focus on cures instead of treatments for complex, often chronic, diseases.

Information obtained from http://www.nibib.nih.gov/science-education/science-topics/tissue-engineering-and-regenerative-medicine

Dr Steven Thng delivers his talk.

Dr Thng receives a token of appreciation from Dr Ho.

MTA2015 presents the latest developments in precision engineering

MTA2015, the precision engineering event for the manufacturing industry, was held from 14 to 17 April 2015, at Singapore Expo.

The event, organised by Singapore Exhibition Services, featured the displays of 350 companies from 27 countries, and attracted over 12,000 trade attendees comprising exhibitors, visitors, conference speakers and delegates, and press members. IES was a supporting organisation at MTA 2015 and had a booth at the exhibition, presenting information on the engineering sector.

The exhibitors come from industries and sectors such as aerospace, complex equipment, energy, electronics, medical technology and oil & gas / marine & offshore engineering, and presented some of the world's most progressive precision engineering and machine tool technologies that are available in today's marketplace.

Mr Lee Yi Shyan, Senior Minister of State, Ministry of Trade and Industry and Ministry of National Development, was the Guest-of-Honour at the Official Opening of MTA2015.

"At one-fifth of Singapore's GDP and employing half a million people, our manufacturing sector is re-structuring. It is heading towards high value-added engineering production. A number of our firms enjoy technology and market leadership in sub-sectors such as semiconductor equipment, diagnostic tools, biologics, hard disk drive media and offshore oil and gas platforms. Building on these achievements, we aspire to become an advanced manufacturing hub of tomorrow", said Mr Lee.

Mr Lee also stressed that manufacturing firms need to stay ahead of competition by aggressive adoption of the latest technologies, including additive manufacturing and robotics.

As manufacturing is a key sector in Singapore, there are intentions to restructure and build an even bigger industry to develop new technologies.

The Guest-of-Honour, Mr Lee Yi Shyan, Senior Minister of State, Ministry of Trade and Industry and Ministry of National Development, tours the exhibition. Image by Singapore Exhibition Services.

'Echoes of Nature' - a talk on photography

President of the Photographic Society of Singapore, Mr Goh Kim Hui, delivers his talk.

IES Photography Club held a talk on 'Echoes of Nature', in collaboration with the Photographic Society of Singapore (PSS). The talk, presented by the President of PSS, Mr Goh Kim Hui, was held at PSS Gallery in Selegie Arts Centre, on 15 May.

Mr Goh expressed his enthusiasm for the upcoming WES 'About Climate Change' competition and shared his insights on nature photography. He shared his understanding of yin and yang (Chinese philosophy) and how he uses it along with the five major elements of nature (metal, wood, water, fire and earth), during his photo shoots. Mr Goh also stated that the sky and people are a part of nature and add to the depth of the photography.

Sharing photographs from his travels in China, Inner Mongolia, Indonesia and Japan (in the aftermath of the tsunami), Mr Goh provided a vivid showcase on how he had made use of the five elements to capture pictures that complement the philosophy of yin and yang, such as images with forests (wood) and a river (water), or a lake (water) reflecting a fire nearby. Mr Goh applies the principle of yin and yang in his photography - everything in the universe is made of forces opposing yet complementing each other.

Mr Goh concluded the talk by reminding everyone to treasure the environment as nature is susceptible to human destruction. If nature is gone, there will be no more environmental images available, he said.

Keen photographers also have the chance to go on a photography expedition with Mr Goh and fellow photography enthusiasts from PSS, on their next visit to Inner Mongolia in September this year. Please contact PSS for more details of the expedition.

Philips Lumileds Singapore Plant

The manufacturing facility won a Green Mark Platinum Award, under the Existing Buildings category, at BCA AWARDS 2015.

The Philips Lumileds Singapore Plant is located in Yishun Avenue 7.

Founded in 1999, Philips Lumileds Lighting Company is a leading manufacturer of high-power LEDs and a pioneer in the use of solid-state lighting solutions for everyday purposes including automotive lighting, computer displays, LCD televisions, signage and signalling and general lighting.

The company's patented LUXEON power light sources combine the brightness of conventional lighting with the small footprint, long life and other advantages of LEDs.

In November 2007, Philips Lumileds officially opened its new production facility in Singapore. The LUXEON high power LED plant, its first outside of Silicon Valley, extended Philips Lighting's LED leadership while accelerating the growth of the solid state lighting industry.

Located at Yishun Avenue 7, the Philips Lumileds Singapore plant, which operates round-the-clock, comprises two blocks - the Main Building and the Annex Building. The facility has a total Gross Floor Area of 41,716 m^2 and an open car park area of 1,732 m^2.

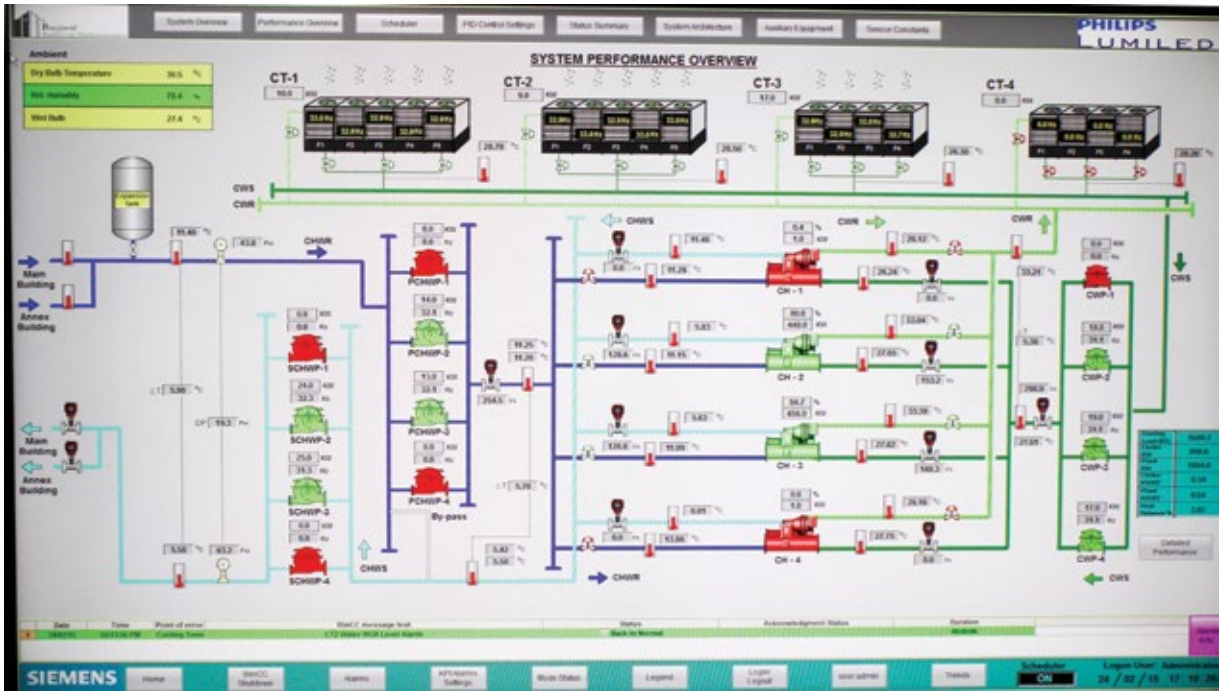
Initiatives in four key areas contributed to Philips Lumileds Singapore becoming the first manufacturing plant in the country to receive the Green Mark Platinum Award.

- The central chiller plant underwent optimisation to achieve an average plant efficiency of 0.64 kW/RT.
- LED lights were installed throughout the building, improving the lighting power budget, in accordance with the Singapore Standards Code of Practice.
- Extensive water recycling efforts have led to significant water savings and the achievement of PUB's Water Efficient Building (Gold) certification.
- Sustainable operations and management are strongly encouraged, through recycling efforts as well as through the implementation of educational and awareness programmes involving employees, contractors and vendors.

CHILLER PLANT OPTIMISATION

To improve overall operational efficiency, the obvious option for Philips Lumileds Singapore was to replace its 14-year-old chiller plant at significant expense. Instead, Philips Lumileds Singapore decided to collaborate with Barghest Building Performance (BBP), a Singapore-based energy efficiency service company in the intelligent building space, which focuses on extracting the best performance from existing central chiller plants. BBP uses data analytics, cloud-based optimisation and deep Heating, Ventilating and Air-Conditioning (HVAC) domain expertise to deliver energy savings for its clients.

BBP provided an alternative to Philips Lumileds Singapore,



The chiller plant management system enables the required cooling to be delivered in an energy-efficient manner.

By optimising its 14-year-old chiller plant, Philips Lumileds Singapore was able to achieve energy-efficient operations.

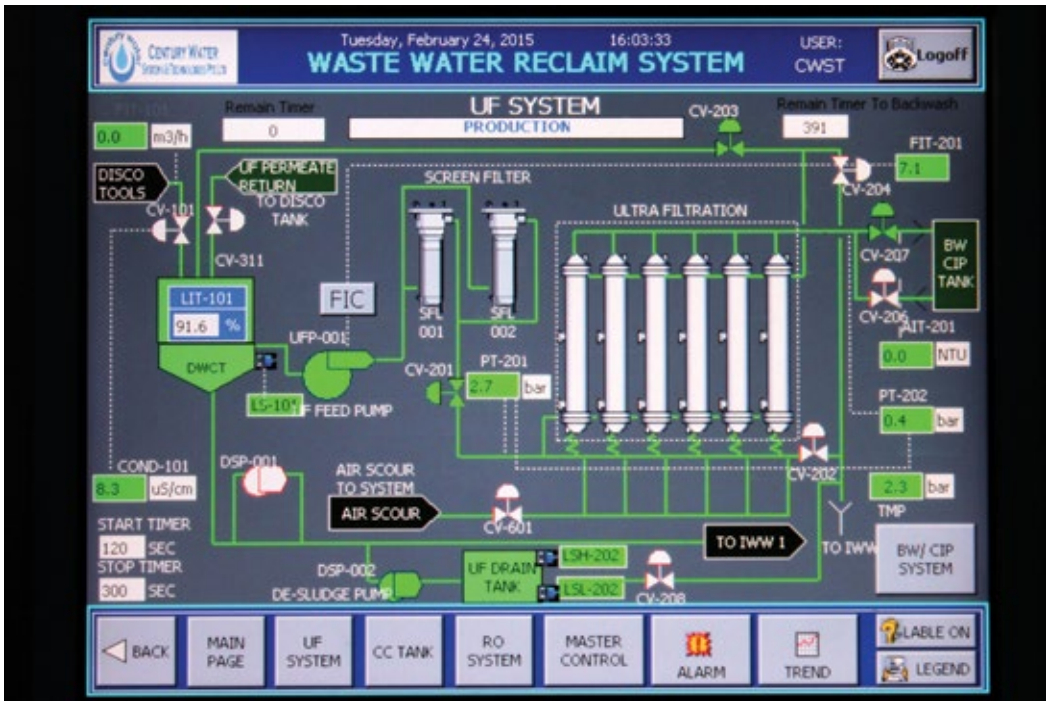
that is, optimising the current chiller plant, to deliver the required cooling in an energy-efficient manner.

The optimisation solution provided by BBP includes the connection of variable speed drives to the chilled water and condenser water pumps as well as to the cooling towers.

Further, in line with the BCA Green Mark requirements for effective measurement and verification, dedicated digital power meters have been connected to all major equipment like chillers, cooling towers and pumps. Every chiller is connected to a magnetic, full bored flow

Instrumentation panels enable the remote monitoring and control of the air-conditioning system.

Installation of next-gen LED lighting improved the lighting power budget.



The waste water reclamation system helps to reduce the consumption of potable water.

meter and high accuracy temperature sensors on both the chilled water and condenser water sections. The heat balance is determined at every chiller and header level.

BBP also connected each site to a cloud-based central system, enabling Philips Lumileds Singapore to have access to remote monitoring, auto reporting and other features to improve day-to-day operations.

As a result of all these efforts, Philips Lumileds Singapore achieved a 27% improvement in the chiller plant's efficiency, without needing to replace major equipment or disrupt operations at the plant. With sustained savings of 30% of initial energy consumption, Philips Lumileds Singapore was able to realise a reduction of S$ 700,000 in annual energy costs.

Performance Contracting

In order to ensure sustained savings over time, Philips Lumileds Singapore has entered into a long-term performance contract with BBP, under which, BBP will be paid only upon measurable performance improvements at the Philips Lumileds Singapore plant. The efficiency improvements will be verified on a monthly basis by an independent third party, DNV GL, through the DNV GL, Clean Technology Centre in Singapore.

For its next project, BBP plans to evaluate and optimise the plant and office air handling unit system, in order to reduce energy consumption.

INSTALLATION OF LED LIGHTING

Being in the LED business, lighting optimisation was an

obvious area of interest for Philips Lumileds Singapore. The company thus took steps to replace light fixtures, chiefly by installing a newly launched generation of next-gen LED lighting. The improvement in lighting power budget, compared to the code, is expected to reach 40%.

ACHIEVING WATER EFFICIENCY

Philips Lumileds is also focusing on water efficiency. It has installed a water recycling plant that has a capacity of 300,000 m^3/year, to capture condensate water from the air handling units (AHUs), production waste water as well as water rejected by the reverse osmosis system. The requirement for potable water is significantly reduced, due to the utilisation of recycled water and NEWater.

Smart meters capture the daily water consumption and link it to the building management system (BMS) and also to PUB, for monitoring purposes.

SUSTAINABLE OPERATIONS AND MANAGEMENT

Besides encouraging recycling efforts among employees, Philips Lumileds Singapore conducts awareness programmes for employees, suppliers and contractors, to promote environmental sustainability including energy and water conservation.

FUTURE EFFORTS

Although the Green Mark Platinum Award is a milestone for the Philips Lumileds Singapore plant, the site team is continuing its efforts to improve operations and reduce environmental impact. The Philips Lumileds Singapore team is continuing its programme, started three years ago, to reduce energy intensity and water usage as well as increase environmental awareness among all stakeholders.

(With effect from 1 April 2015, Philips Lumileds Singapore Pte Ltd has changed its name to Lumileds Singapore Pte Ltd).

Equipment required for ensuring process water quality include filters (image above) and reverse osmosis high pressure pumps (image below).

The company encourages recycling efforts.

Transforming infrastructure development and management

Rapid advances in software are making it possible to realise enormous benefits.

The Singapore Government is promoting the adoption of Building Information Modelling (BIM) by the building and construction industry, through a series of measures including financial incentives as well as mandatory regulations.

This is because of the potential benefits that can be realised by all stakeholders in a project, through the implementation of BIM.

BIM enables a three-dimensional model of a project and drawings to be shared by different project team members, enabling them to analyse and detect potential clashes and resolve them, thus eliminating the need to rework at the construction stage. The greater integration and teamwork among the various stakeholders will increase productivity, reduce wastage and improve logistics.

However, with greater levels of sophistication in the implementation of BIM processes and with enabling software tools, organisations can reap huge economic benefits across the life-cycle of infrastructure assets, right from planning, design and construction, through to operation, maintenance and decommissioning, according to Mr Brian Middleton, Senior Industry Solutions Director, Bentley Systems.

A global leader in its field, Bentley Systems provides architects, engineers, geospatial professionals, constructors, and owner-operators with comprehensive software solutions for sustaining infrastructure. Bentley Systems applies information mobility to improve asset performance by leveraging information modelling through integrated projects for intelligent infrastructure. Its solutions encompass the MicroStation platform for infrastructure design and modelling, the ProjectWise platform for infrastructure

Mr Brian Middleton

project team collaboration and work sharing, and the AssetWise platform for infrastructure asset operations - all supporting a broad portfolio of interoperable applications and complemented by worldwide professional services.

Said Mr Middleton, "Organisations must start with the end in mind, which is the long-term sustainability and economic viability of the asset".

"This is because, over a 50-year period, approximately 85% to 90% of the total cost ofan infrastructure asset is due to the operational and maintenance activities, compared to only 10% to 15% of the cost incurred for its design and construction", he added.

Mr Middleton said that with 'exemplar' organisations who take a long-term view of their assets, it is possible to conclude outcome-based contracts. This is much more than merely providing software, because the software solutions provider is paid by the customer only when a specific outcome, as defined in the contract, is obtained.

"It will fundamentally change the way things are done", said Mr Middleton.

Sophistication Levels In BIM Implementation

Level 0 BIM - 2D
In its simplest form, Level 0 effectively means 2D CAD drafting mainly for production information. Output and distribution is via paper and / or electronic prints.

Level 1 BIM - 3D with process and standards
This typically comprises a mixture of 3D CAD, and 2D. CAD standards are managed to BS 1192:2007, and electronic sharing of data is carried out in a common data environment (CDE). This is standard capability in any modern organisation, but limited in benefit due to the multiple and incompatible CAD tools.

Level 2 BIM - Collaboration across the supply chain
This is collaborative BIM - The collaboration is where information is exchanged between different groups. Design information is shared through a common file format, which enables data from different teams to be combined in order to make a federated BIM model. It must be possible to export the CAD software that each party used to one of the open standards file formats such as IFC (Industry Foundation Class) or COBie (Construction Operations Building Information Exchange). Neither format referenced here is currently fit for purpose for civil / linear assets.

Level 3 BIM - Interoperability across all data sources
This represents full collaboration capabilities and interoperability between all engineering disciplines including the management of and access to all related information (graphical, non-graphical, structured and unstructured data). Level 3 provides stakeholders rule- and role-based access to all information.

Level 4 BIM - Predictive analysis for effective asset performance management
Still to be fully defined, however, Level 4 is anticipated to enable infrastructure owners to benefit from all of the information captured in the previous BIM levels to provide predictive outcomes.

INTRODUCING THE CONNECT EDITION

THE NEXT GENERATION OF INFRASTRUCTURE SOFTWARE

SUNTEC, SINGAPORE - 3-4 JUNE, 2015

Join us at a Bentley CONNECTION Event near you

Increase your ability to deliver the best performing buildings, bridges, roads, power plants, utility networks, mines, and other infrastructure on time, on budget, and with less risk.

See how the next generation of infrastructure software will change your game.

Join us at this Connection event at Suntec in Singapore on 3-4 June, 2015 for the premier event for infrastructure professionals. Discover the CONNECT Edition – the next generation infrastructure software environment that connects the entire project team.

Network with your peers. Share best practices.

Keynotes | Application Seminars | Industry Forums | CONNECT Edition | LEARNing Day

Reserve your spot today.

connection.bentley.com/singapore

Bentley
Sustaining Infrastructure

© 2015 Bentley Systems, Incorporated. Bentley and the "B" Bentley logo are either registered or unregistered trademarks or service marks of Bentley Systems, Incorporated or one of its direct or indirect wholly owned subsidiaries. Other brands and product names are trademarks of their respective owners.

Connecting the last mile of the journey

by Isa Kamari and Jane Tan, Land Transport Authority of Singapore

Like many cities, Singapore faces many significant challenges in meeting the mobility needs of a rapidly increasing population. On top of the limited physical space available for urban development, the rapidly ageing population has brought about even greater challenges in public transportation.

Currently about 60% of the people living in Singapore use public transport daily and many commuter infrastructures have been built to support the growth. For the increasing majority who have to depend on public transport for their daily commute, it is important that the Land Transport Authority of Singapore (LTA) ensures that commuter infrastructures for walking and transit are well planned and built. This includes thorough reviews and making significant improvements to older commuter infrastructures.

To cater for the diverse needs of the public, LTA has focused on active communication and engagement with the communities. Through this process, LTA has attained a good understanding of commuters' mobility needs and the ability to address them effectively.

This article provides an overview of LTA's approach in enhancing the physical mobility of commuters. It highlights the various completed, ongoing and new pedestrian / commuter-friendly programmes as well as the concepts and strategies employed by LTA in managing their implementation in a progressive manner.

INTRODUCTION

Over the years, LTA has been building commuter infrastructures island-wide, to facilitate seamless travel for commuters. With the rapidly ageing population, some of these existing commuter infrastructures are inevitably not elderly-friendly enough. Retrofitting and rebuilding of these infrastructures are necessary to address the needs of the elderly and less mobile.

To thoroughly understand and capture the needs of the ageing population, feedback was gathered through LTA's various communication platforms. The key feedback received encompasses the need for more barrier-free access at pedestrian facilities, comprehensive covered linkway networks, and the integration of the various key transport nodes with other amenities.

In the planning and design of new commuter infrastructures, LTA, in collaboration with other government agencies, has been ensuring that accessibility, connectivity and integration are put in place. Efforts have also been made by LTA to reassess the public's usage of all existing commuter facilities, to identify areas for improvements and enhancements. Various retrofitting / redevelopment programmes were subsequently established.

The strategy employed to implement these programmes included thorough reviews of the existing policies and technical guidelines, as well as the formulation of new ones. These reviews have helped LTA to assess the viability of implementing the accessibility, connectivity and integration programmes more effectively. The policies and guidelines also set the basis for LTA to prioritise the island-wide project implementation systematically and have successfully guided LTA in the management of public expectations.

The various completed accessibility, connectivity and integration programmes have created a better walking and transit environment for the commuting public. Going forward, LTA has embarked on new initiatives to connect the first and last mile of the journey for everyone.

BARRIER-FREE ACCESSIBILITY PROGRAMMES

The barrier-free accessibility (BFA) programmes cover the enhancements of accessibility at existing transport nodes [Mass Rapid Transit (MRT) and Light Rail Transit (LRT) stations and bus interchanges] and commuter facilities (bus stops, taxi shelters, pickup points, pedestrian overhead bridges and covered linkways). To ensure that the barrier-free initiatives are well tailored to the needs of the targeted users, LTA works closely with numerous social and other organisations such as the National Council of Social Services, Handicaps Welfare Association, Singapore Association for the Visually Handicapped, and the Building and Construction Authority. Through

Land Transport Authority

We Keep Your World Moving

We introduced Asia's first automated underground heavy rail system.

We also built Southeast Asia's longest underground expressway.

Now, we are mapping out much more for Singapore's land transport system and we would like you to join us on this journey.

At the Land Transport Authority (LTA), we are responsible for planning, operating, and maintaining Singapore's land transport infrastructure and systems. Our people take pride in keeping this dynamic city of over 5 million on the move, connecting people to their goals, aspirations and lifestyles.

Imagine a smart and sustainable land transport system that provides greater connectivity to every part of the island, as well as a seamless and more comfortable commuting experience. You could be part of the team to make it possible because we are constantly crossing technological frontiers in developing innovative land transport solutions.

If you share our vision to create a people-centred land transport system and aspire to enhance the everyday lives of Singaporeans, we invite you to explore the career opportunities here at LTA.

We are hiring for the following positions:

- **Senior / Executive Project Engineer, Signalling**
- **Senior / Executive Project Engineer, Electrical & Mechanical Services**
- **Senior Engineer, Road Tunnel Facility**
- **Manager / Principal Engineer, Rolling Stock (Mechanical)**
- **Senior / Executive Engineer, Mechanical**
- **Senior / Executive Project Engineer, Network Renewal (Systems)**
- **Senior / Executive Engineer, Signals, Communications and Control**
- **Senior / Executive Project Engineer, Re-Signalling (North-South / East-West Lines)**
- **Deputy / Assistant Manager, Fare Operations**
- **Deputy / Assistant Manager, Bus Operations**
- **Senior Manager, Bus & Fare Operations**
- **Deputy / Assistant Manager, Bus Service Development**
- **Deputy / Assistant Programme Planning Manager (Electrical & Mechanical)**
- **Deputy / Assistant Contracts Manager (Electrical & Mechanical)**
- **Executive Engineer, Traffic Management**

For detailed job description, please visit our website at **www.lta.gov.sg** or Singapore Public Service Job Portal at **www.careers.gov.sg**.

To apply, please send your resume to **LTA-Join_Us@lta.gov.sg** indicating ref. no. **TSE0515 – "Job Title"** in the email subject line. Your application will be treated in strict confidence and you will be notified if you are shortlisted.

numerous engagements and consultations, LTA adopted the international practices applicable for BFA design and promulgated them for implementation in all transport nodes and commuter facilities.

With the completion of the BFA programmes, about 95% of pedestrian routes connected to and within 400 m of train stations (MRT and LRT), are barrier-free. In essence, the BFA programmes along pedestrian routes and at transport nodes have enabled the commuters to start their journey from home to their destinations, without facing any physical barrier. The following describes the works involved in carrying out the various BFA programmes:

Train stations

The concourse floor levels of all train stations are built higher than the road and footpath levels. The intent is to protect the station entrances in the event of flooding, during the monsoon season. These level differences are mitigated by steps which posed a challenge to the wheel-chair bound commuters who wished to travel by rail. A five-year station upgrading programme was initiated in Year 2000, to provide barrier-free facilities at all stations along the first two rail transit lines in Singapore - the North-South and East-West lines. The upgrading entailed providing at least one barrier-free entrance with ramp to the concourse level and a lift to the train platform level, at each station. A tactile guidance system has also been provided, which helps to create a route within the stations to guide the visually impaired commuters from the moment they arrive at the station entrance to the moment they reach the train platform. All public toilets at the stations were also re-configured to be elderly and handicapped friendly. Larger toilet cubicles with grab bars and adequate turning space for wheel-chairs have been provided.

A lift is provided from the concourse to the train platform level.

A ramp is provided at the entrance of the train station.

Construction activities were carefully phased at existing stations to minimise disruptions to commuters. In 2006, LTA further enhanced barrier-free accessibility at other station entrances, through a second phase upgrading programme. This was completed in 2011 and, to-date, 85% of all existing train stations have at least two BFA routes.

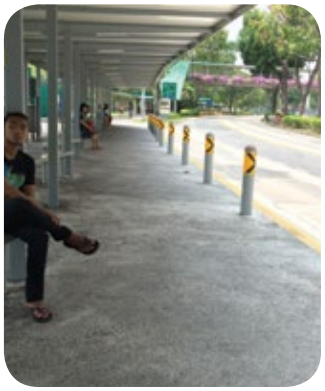
Pedestrian walkways

The BFA upgrading of pedestrian walkways included combing through the entire pedestrian walkway system island-wide, to remove obstacles and widen the narrow walkways, so that clear passageways can be provided for the wheelchair-bound. This also caters for those using strollers, walkers and trolleys. Kerb ramps have been provided for pedestrians with mobility impairments, who have trouble stepping up and down high road kerbs. To aid the visually impaired, tactile guidance systems have been installed at walkways, road junctions and crossings.

Bus stops and taxi shelters

Bus stops and taxi shelters are designed to be reasonably comfortable for people. Their design includes seats for the elderly and sufficient circulation space for people in wheel-chairs. Under the existing configuration of roads, some of the older bus stops were built on higher terrain,

1.5 m wide walkway, with tactile guidance system and kerb ramp.



Sloped floors at retrofitted bus stop.

Ramp and tactile guidance system at retrofitted taxi shelter.

mitigated by steps which posed considerable challenges to the elderly and wheel-chair bound commuters.

A programme to replace steps at bus stops with ramps was carried out, in tandem with the introduction of wheel-chair accessible public buses. This has enabled wheel-chair bound commuters to take public buses conveniently. Similar BFA improvements were also implemented at taxi shelters and passenger pick-up / drop-off points, by mitigating the level differences with ramps.

Pedestrian overhead bridges and underpasses

Pedestrian overhead bridges (POBs) and underpasses allow for uninterrupted pedestrian movement by separating them from vehicular traffic. Many of the POBs and underpasses were built decades ago, when many Singaporeans were much younger and were fit enough to climb staircases. As the population aged, barrier-free measures such as ramps have been progressively introduced to POBs and underpasses, wherever there was sufficient land space along the roadside to locate them. To manage the implementation, LTA prioritised the retrofitting of POBs and underpasses at areas with heavier pedestrian usage.

The design guidelines for POBs and underpasses were also reviewed. Lower and wider steps were introduced at all new POBs and underpasses, to ease the effort in climbing stairs. Colour contrasting tactile guidance systems were provided along the lateral edges of the steps to enhance clarity for those who access them at night and to aid the visually impaired.

BFA ramps provided at pedestrian overhead bridge.

BFA ramps provided at underpass.

While LTA tries to retrofit ramps to more POBs, it is sometimes not viable to do so due to insufficient land space to locate the ramps and LTA has to continuously seek alternative BFA measures. Although the ramps at POBs have been very useful to the wheel-chair bound, the feedback from the elderly has been that using the ramps is too tedious. In view of this, LTA has re-evaluated the provision of ramps and initiated the retrofitting of heavily used POBs with lifts.

For a start, consideration has been given to the installation of lifts at POBs next to train stations where ramps for POBs and alternative road level crossings are not feasible. LTA has to take into account the technical feasibility and cost-effectiveness of the installation of these lifts, as well as check the usage levels of these POBs. Six POBs met these considerations and were selected for retrofitting with lifts, to improve BFA at major transport nodes. The retrofitting works for these POBs, at Aljunied, Bishan, Khatib, Kranji, Sengkang and Yew Tee stations, were completed in early 2014.

The installation of lifts at these POBs has enhanced the public transport network by enabling the elderly and less mobile to gain greater access to train stations. Hence, LTA subsequently reviewed the guidelines to provide lifts to POBs that are further away from train stations. POBs that are within a 200 m radius of train stations and bus interchanges have been identified for lift retrofitting.

Site studies were carried out to ensure that there is no alternative road level crossing near the POBs and that the bridges are gainfully utilised. Currently LTA is retrofitting lifts to 40 more POBs, under an enhanced barrier-free accessibility programme. This is scheduled to be completed progressively from 2016 to 2018.

THE CONNECTIVITY PROGRAMME

With Singapore's hot and wet weather, it is very important to provide commuters with a comfortable walking environment. To facilitate convenient and comfortable

Lift retrofitted at pedestrian overhead bridge.

Covered connectivity between bus interchange and train station.

Covered connectivity between school and bus stop.

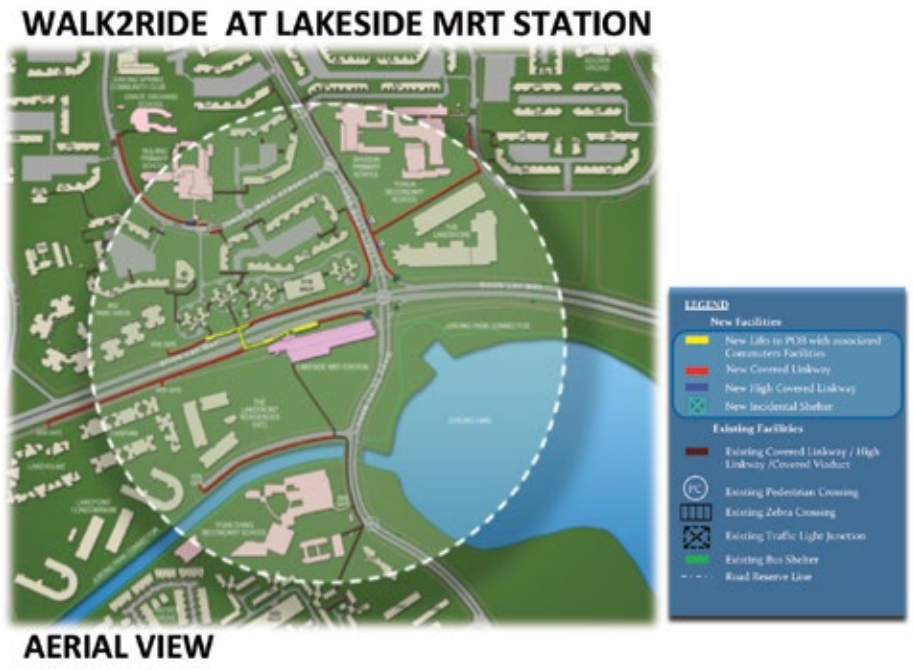
inter-modal transfers, covered linkways have been provided between transport nodes and commuter facilities, under an island-wide covered connectivity programme.

To manage the programme implementation prudently and effectively, a set of guiding principles was established. The general principle for providing covered linkways is to link transport nodes to nearby commuter facilities such as bus stops, taxi shelters and passenger pick-up points. Selected amenities like schools and hospitals within a radius of 200 m from these transport nodes were included. At areas where there are large catchments of commuters / users, higher priority was accorded for the implementation. In terms of design and construction, LTA created design prototypes of simple and elegant covered linkways that are easy to build and maintain. The connectivity programme was completed in end 2012.

In the last island-wide connectivity programme, the policy allowed for provision of covered linkways within 200 m of transport nodes. Through site audits, feedback and engagements with the public, the guidelines were subsequently revised to provide more covered linkways covering wider areas around train stations and bus interchanges.

A 'Walk2Ride' connectivity programme, which aims to enhance and strengthen connectivity networks around train stations, by leveraging on existing linkway networks, and connecting them to trip-generating hubs, was initiated in 2012. The framework aims to provide connectivity within a 400 m radius from the MRT stations and a 200 m radius from the LRT stations, bus interchanges and bus shelters with high passenger boarding figures.

The most important strategy in implementing the Walk2Ride connectivity programme is to verify and understand how commuters travel from their homes to transport nodes / destinations, the difficulties they experience in their daily commute and the improvements needed to enhance their travelling experience. All these were carried out by assigning project officers to walk the ground and conduct site surveys and studies on the way commuters travelled in areas within 400 m of each of the 100 existing MRT stations and within 200 m of each of the 38 LRT stations.



Walk2Ride Master Plan at Lakeside station.

Through this process, uncovered linkages and more direct routes that commuters take to access transport nodes were identified. Existing barrier-free ramps built earlier by the various estates' town councils were identified so that the uncovered parts could be covered and linked to existing covered linkway networks. Amenities that are trip generation hubs, not currently linked to transport nodes, were also identified for covered connectivity, if they are within the defined radius of transport nodes.

All these findings were diligently translated into an island-wide Walk2Ride Master

Plan. The master plan was then shared with the local community advisers and grassroots organisations, so that the residents of each estate could give their views and suggestions prior to its implementation. The consultative process were very useful, as residents were supportive and felt that they were given the opportunities to contribute towards making their estate more accessible and liveable.

As some areas are managed by other agencies like Housing & Development Board and Town Councils, LTA worked closely with them for the implementation of the connectivity proposals. A technical manual for implementation of the Walk2Ride programme was developed to assist architects and contractors in the implementation. Currently being implemented at a cost of S$ 330 million, the island-wide Walk2Ride connectivity programme will involve the construction of approximately 200 km of covered linkways. It is scheduled to be completed progressively from 2016 to 2018.

INTEGRATION OF TRANSPORT NODES WITH AMENITIES

As LTA has designed the public transport system based on a 'hub and spoke' model, train stations and bus interchanges become the focal points where people make transfers to continue their journeys. LTA has since worked with various government agencies, private developers and transport operators, on the relocation of older bus interchanges and their integration with commercial / residential developments and train stations.

Currently, bus interchanges at towns like Ang Mo Kio, Bedok, Boon Lay, Clementi, Sengkang, Serangoon and Toa Payoh are fully integrated with the train stations and adjoining commercial developments. These integrated transport hubs (ITHs), with air-conditioned bus interchanges and train stations, are also co-located with retail and commercial activities. They allow transfers to be done more efficiently and comfortably, and commuters enjoy the added convenience of being able to shop before transferring to buses or trains. The integration has consequentially rejuvenated and revived some of these older towns.

More integration

Programmes to redevelop bus interchanges in towns like Bukit Panjang, Hougang, Joo Koon, Jurong East and Yishun, over the next 10 years, are in place. They will be built in tandem with re-developments in the respective areas, to better integrate the transport hubs with the surrounding amenities.

As more ITHs are built, LTA will also look into introducing more retail spaces to inject buzz into these transport nodes. This will transform the ITHs into lifestyle hubs that are vibrant and highly accessible meeting points for the community. Barrier-free underground and overhead covered connectivity will be introduced to complement the overall accessibility of the network.

This integration requires a regulatory framework to ensure that a well designed network of underpasses connecting major office buildings and subways of train stations, including accessways through private development sites, is in place. At the macro level, LTA has to work with the Urban Redevelopment Authority (URA) to regulate the integration of new developments under the Government Land Sales programme. At the micro level, the the proposals for integration have to be reviewed by LTA's Architecture Design Panel to ensure that the integration is well connected for functionality, convenience and aesthetics.

CYCLING FACILITIES

In recent years, cycling has become increasingly popular in Singapore. Besides cycling for recreation, it is also an alternative mode of transport for people, enabling them

Aerial view of the proposed integration at Bukit Panjang Town.

Artist's impression of integration with future developments at Bukit Panjang Town.

to make short-distance intra-town trips from residential precincts to train stations, bus interchanges and local amenities.

Ideally, it is safer to segregate cycling from vehicular traffic within the road carriageway, as seen in some big cities. However, with Singapore's limited land space, the provision of independent cycling paths within the road carriageway is not a viable option. Instead, the creation of shared space on pedestrian walkways for cyclists is deemed more tenable. To facilitate cycling, LTA, in partnership with various community stakeholders and agencies has rolled out programmes to design and construct dedicated cycling paths to co-exist next to pedestrian walkways at selected residential towns like Tampines, Yishun, Sembawang, Pasir Ris, Taman Jurong and Changi-Simei. Going forward, LTA plans to extend dedicated cycling paths at more residential towns.

Complementing this programme, LTA has also provided more bicycle parking facilities to facilitate cycling to train stations. To-date 3,000 additional bicycle parking racks, comprising both single-tier and double-tier racks have been added to train stations. By end 2015, another 500 bicycle parking racks will have been added to 11 more train stations.

Dedicated cycling path that co-exists with the pedestrian walkway.

Two-tier bicycle racks at a train station.

IMPROVEMENTS TO TRAIN STATIONS

The increase in the population of residents and visitors has put a strain on Singapore's public transport system. Train stations have become very congested, hampering the movement of commuters. To ease the overcrowding and increase mobility, a pilot project under the Jurong East Modification Programme (JEMP) was implemented, as a result of which a new platform, entrances, and an additional track were built at this station. The work was completed in May 2011.

Having successfully piloted such a project, LTA has expanded the programme to retrofit more congested stations with extended platforms and additional entrances. These are challenging programmes for LTA, as construction works need to be carried out without causing too much disruption to train operation and to commuters at these stations.

Through surveys and commuter load counts, Clementi, Commonwealth and Queenstown stations were identified as the most critically congested stations. Hence, high priority was given to retrofit these three stations with additional link bridges which function as new entrances. Through this prioritisation process, congested stations will eventually be retrofitted to cope with the increased usage of the rail transit system.

CONCLUSION

In summary, the last mile of the commuters' journey has been thoroughly and specifically addressed by implementing more accessibility, covered connectivity, and enhanced integration of transport nodes and amenities. In addition, new cycling facilities have been developed and station improvements undertaken to cater for the increase in the commuting population. All these initiatives and programmes implemented by LTA will make walking and travelling a breeze for everyone.

Artist's impression of the proposed additional platform and entrances at Clementi station.

Efficiency - the key to meeting global energy demand

In its World Energy Outlook 2013, the International Energy Agency (IEA) forecast that, taking the effects of current energy and climate-protection targets into account, global energy demand will increase by one third between 2011 and 2035. Around two-thirds of the increase is expected to take place in Asia, excluding South Korea and Japan. IEA estimates that half of the new power stations built worldwide by 2035 will use renewable sources of energy. These sources will cover 31% of global electricity needs by 2035, compared to 20% in 2011.

Efficient cross-border collaborations

In order to achieve higher yields and more efficiency, it would make sense to distribute capacities, not only within each country, but also internationally - within the EU, for example. According to calculations made by Siemens, transferring the planned expansion of solar energy systems from the UK and Germany to Spain and Italy and that of wind power from southern Europe to the North Sea and the Baltic Sea, would result in improved efficiency and cost savings.

If implemented, it is estimated that the amount of photovoltaic capacity needed would be reduced by 39 gigawatts (GW), while wind energy capacity would also be reduced by 16 GW, even though total power output would remain the same. Implementing this would require construction of additional power lines. However, the total investment needed would drop by US$ 45 billion.

The need for efficiency

According to IEA, deep-sea drilling and the discovery of unconventional oil and natural gas deposits are impacting the global distribution of energy reserves. This development is creating new regional differences in energy prices, with Europe and Japan being the main losers.

Energy costs can have a big impact on a company's competitiveness. This is especially the case in energy-intensive sectors, such as the chemical, steel, aluminum, and paper industries. As a result, gains in energy efficiency are becoming increasingly important. In many cases, the high purchase price of energy-efficient industrial equipment, motors, and lighting systems can be recouped within a few years through cost savings.

Currently, German consumers are already paying two to three times as much for electricity as customers in the US. In 2012, the amount of energy needed to produce a unit of GDP declined by 1.5% worldwide. In the US, it dropped by almost 4.5% and, in China, by 4%.

"Energy efficiency is absolutely crucial if you want to remain competitive", says IEA Chief Economist Fatih Birol.

Standards for energy efficiency

The IEA forecasts that regions such as China, India, and Africa will achieve the biggest improvements in energy intensity by 2035. It also estimates that the efficiency measures that are currently being discussed by governments will lead to additional savings of 910 million tons of oil equivalent (Mtoe) by 2035.

Currently, the EU's energy efficiency directive stipulates that between 2014 and 2020, member states must reduce the average amount of end energy sold by 1.5% annually, compared to the average amount sold between 2010 and 2012. According to the German Energy Agency (dena), countries could enforce the energy saving target on energy supply companies. Alternatively, they could use instruments such as subsidies and energy taxes.

Several countries, such as the UK, France, and Denmark, have already introduced such energy efficiency requirements nationally. In Denmark, grid operators are required to meet established energy-savings targets. To do this, they are implementing energy efficiency measures either at their customers' premises or through selected energy service providers.

In Asia, an example of this can be found in the Chinese province of Hebei where a new energy efficiency standard is being implemented. The standard was developed by dena in cooperation with the Center of Science and Technology of Construction (CSTC), which is under the control of the Chinese Construction Ministry. Already, one of the high-rise buildings in the province now meets the new standard. The ministry aims to use this provincial standard as a benchmark for introducing a nationwide energy standard for new buildings.

"The building consumes around 75% less energy than new buildings usually do in China", says Stephan Kohler, Chief Executive of dena.

Efficient collaboration

Electricity is the lifeblood of today's cities. Everything, from a city's infrastructure and transport system to its offices and factories, relies on the constant supply of electricity in order to function effectively. As such, cities need to be efficient in energy production.

By collaborating on the production of energy globally or within a region, countries and cities will be better able to identify and focus on the most efficient method of energy production. This, coupled with energy efficiency standards that help minimise energy wastage, could be the solution to address the expected rise in energy demand globally.

On top of this, the cost savings involved would enable city planners to redirect these funds into other areas which improve the overall quality of life for citizens, ultimately ensuring the long-term sustainable growth of these cities.

(Adapted from an article written by Sylvia Trage in Siemens' 'Pictures of the Future' magazine, Spring 2014 Edition)

Gas turbine air filter system optimisation

by James DiCampli, P E, GE Power and Water; Jack Pan, GE Power and Water; and Mark Arsenault, American Air Filter Ltd

Proper air filtration is critical to the overall performance and reliability of gas turbines. Fuel costs approach 80% of the life-cycle cost of electricity. Small gains in efficiency can mean huge savings. With fuel costs of around US$ 16.00/mmBTU and higher in certain global regions, operational savings can be achieved through improved compressor performance using High Efficiency Particulate Air (HEPA) filters. Operators can see greatly reduced maintenance costs as a result of a much cleaner engine, quantified by less frequent inspections, fewer shutdowns, and higher availability. HEPA filtration can maintain optimum GT efficiency throughout the life of the filter. This article will explore the decision criteria required in selecting an optimum air filtration solution, with a goal of maximising gas turbine availability and lowering operating costs. Through case studies and analysis, the review will explore the impacts on essential filter parameters and their impact on gas turbine operations and maintenance.

AIR FILTRATION AND CONDITIONING OVERVIEW

Aeroderivative gas turbine ventilation and combustion air filter systems are designed to protect the gas turbine, generator, and equipment compartments from the effects of air-borne dirt, contamination and foreign objects. A number of inlet conditioning options are also available to maximise gas turbine performance.

GE Distributed Power gas turbines use a three-section inlet air filter that mounts directly above the turbine enclosure, conserving space and providing compact, low-pressure loss ducting to the turbine inlet. Figure 1 provides an illustrative example.

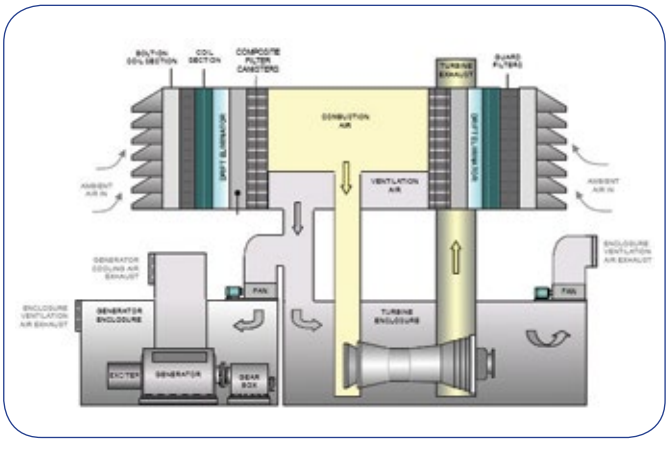


Figure 1: LM6000 gas turbine generator air flow

The ventilation and combustion air system consists of a filter house structure, roof-mounted silencers, fans, and associated ductwork, all located on the turbine and generator enclosures. The filter house is comprised of weather hoods, filter elements, chiller or anti-icing coils, and plenum chamber assembly. Air from the plenum assembly is ducted to the turbine engine intake for combustion and to the turbine and generator compartments for cooling and ventilation. An external ladder and walkway with access doors to the air filter structure enables filter servicing.

A temperature element in the air filter house combustion air section provides inlet temperature information to the control system. Relative humidity sensors measure moisture in the air before it enters the filter housing and activates an alarm if icing conditions exist.

Pressure transmitters sense the pressure difference between the outside air and the combustion air inlet plenum. For example, on a GE LM6000, if the differential pressure reaches -5 in-Wg (-127 mm), the control system activates an alarm, an indication of filter clogging. If the differential pressure reaches -8 in-Wg (-203 mm), the control system activates a load reduction. Another pressure differential transmitter monitors total pressure drop at the ventilation air plenum and activates an alarm if the pressure differential reaches -5 in-Wg (-127 mm).

Ventilation air is ducted from the ventilation plenum directly into the turbine compartment. One of the two turbine compartment fan assemblies draws air from the inlet air filtration system through the turbine compartment and expels it to an air exhaust stack that is equipped with a silencer that limits the transmitted noise.

COMPONENT DESCRIPTION

Weather hoods and drift eliminators

Air entering the filter house first passes through (optional) weather hoods, drift eliminators and inlet screens. Weather hoods protect filters from rain, snow and sun. Weather

hoods are bolted to the inlet side of the left and right coil assemblies (for dual inlet systems). Weather hoods prevent rain and snow from entering the inlet filter house by drawing inlet air upward at lower velocities than that of falling rain and snow. Snow hoods and tropical rain hoods are available for snowy or tropical environments. Inertial moisture separators (vane type separators) are also available to prevent heavy rain or heavy fog mist from entering the filter house.

Filters

A multi-stage filtration system is available, which includes a guard filter upstream of the chiller coils and a set of composite canister 'barrier' or panel-type filter located downstream of the coils. The guard filters (also known as pre-filters) keep the chiller coils clean for maximum heat transfer efficiency and provides supplementary filtration to extend the service life of the composite fine filters.

The fine filter elements are mounted to the filter face of the inlet plenum and extend into the clean air plenum. The elements have extended surface area, large dirt-holding capacity and low-pressure drop.

Air passes through the fine filters and enters the clean air plenum. This fabricated structure is the centre section of the inlet filter assembly and separates ventilation air from combustion air. Combustion air flows through a transition duct from the clean air plenum to the combustion air inlet silencer. Ventilation air flows through transition ducts to the turbine and generator compartment. The inlet silencer is a low-pressure-drop device located in the combustion air stream before the inlet volute. The silencer attenuates noise from the turbine and helps maintain the unit's low noise level.

Inlet cooling and heating

Air-conditioning options include evaporative coolers or optional inlet air chiller coils to maximise gas turbine performance on hot days. Conversely, coils can be used for anti-icing and/or optimising efficiency during partial power operations.

The evaporative cooling system uses the process of evaporation to create a reduction in inlet air temperature. Water is pumped to a header that distributes the water over media blocks that consist of corrugated layers of a fibrous material. Air passing through channels comes into contact with the falling water, causing a portion of the water to evaporate, transferring heat from the air to the water.

Static and pulse filter options

The correct type of filter (pulse or static) should be used for the specific project environmental conditions and specific contaminants.

In general, a pulse or self-cleaning type inlet air filter should be used when the dust loading approaches 0.300 mg/m^3 or higher, or when operating in conditions where dust or sand storms can occur. The ambient air can be tested using a direct read-out device, such as a laser photometer that counts particulates in the air sample.

The AAF ASC Pulse filter system utilises a unique inertial separation system that diverts over 90% of the dust particles from the gas turbine inlet into a secondary air system, via negative pressure. The remaining particles are captured on the surface of the PanelPak filter element, which, in turn, are pulsed off the filters when required. The AAF system prevents re-entrapment of the pulsed particles as they are expelled into the same separation system during the pulse cycle. This allows for continuous operation of the GT during the pulse cycle, while the design provides for a lower pressure drop of the entire inlet system. AAF has over 900 of these units in operation to-date, in many industrial areas and locations with very poor air quality.

Pulse filters can and have been successfully used in very dusty environments, such as steel mills, cement plants, Middle East environments, or areas where sand or dust storms are prevalent, even with high humidity. The pulse controller can be programmed to pulse as the loading requires (eg based on filter pressure drop, ambient relative humidity, hourly, daily, or even continuously). For example, a common recommendation for an installation in a cement factory, is to minimise caking on the filters by automatically pulsing the filters whenever the relative humidity is greater than 80%.

Pulse filters are also utilised when a turbine is being operated in an environment with significant loading of snow or ice crystals. Although a static filter can be used in these environments if there is a properly designed conditioning system upstream (eg heating coils, bleed air or other hot air-conditioning), pulse systems are the most reliable for preventing filters plugging due to cold weather moisture.

Another advantage of pulse filter systems, particularly for peak loading turbines, is that the filters can be pulsed when the unit is not in operation, which provides maximum effectiveness to the pulse cleaning, so the filters can be 'cleaned' and ready for the next start-up.

Static filters can be fitted with inexpensive pre-filters that can be replaced and/or cleaned to extend the life of the barrier elements. However, special pre-filters can become a maintenance item and drive up costs over the life of the project. For example, for areas with a high hydrocarbon loading or areas with cement dusts and frequent high

humidity, pleated composite type pre-filters, rather than the more standard fibrous type, are often required to prevent short barrier filter life. These pre-filters are less expensive and must be replaced (or possibly removed and cleaned) at somewhat frequent intervals.

WATER WASH

Fouling deposits on gas turbine compressor airfoils reduce engine performance. The water wash system provides a mechanism for cleaning engine compressor blades. The aim is to recover power output and heat rate performance by restoring the compressor's flow capacity and efficiency

There are many types of compressor fouling. The type and rate of fouling depend on the environment in which the gas turbine operates and the efficiency level of the inlet filtration.

Among the most common types of contaminants are dirt or soil, sand, coal dust, insects, salt, oil, and even turbine exhaust gas.

Salt also causes corrosion of blading and ductwork and subsequent ingestion of rust and scale. Oil increases the ability of contaminants to cling to compressor passages and airfoils. The type of material that is deposited on the compressor blading influences the method of its removal.

Keeping the compressor internals clean can alleviate a number of problems before they ever become apparent. Besides the obvious benefits of enhanced efficiency (increased power output, lower compressor discharge temperatures etc), keeping the compressor clean will help blades survive longer.

If the compressor is dirty, additional weight is added to the airfoil and this increases the cyclic stress. Also, dirt in the dovetail slots will add to the existing friction loading at the dovetail/slot interface and between the two mechanisms making a blade dovetail failure more likely. Performing thorough water washes with high quality ingredients on a regular basis will help combat these conditions.

Washing utilises liquid detergents, a concentrated solution of water-soluble, surface active agents and emulsifiable solvents produced primarily for cleaning gas turbine compressors, where the intent is to restore performance by removing fouling buildup from compressor components.

Methods of detection

The best method for detecting a fouled compressor is visual inspection. This involves shutting the unit down, removing the inlet plenum inspection hatch, and visually inspecting the compressor inlet, bellmouth, inlet guide vanes, and early stage blading. If there are any deposits, including dust or oily deposits that can be wiped or scraped off these areas, the compressor is fouled sufficiently to affect performance. The initial inspection reveals whether the deposits are oily or dry. For oily deposits, a water-detergent wash is required, followed by clean water rinses. The source of the oil should be located and corrected before cleaning, to prevent recurrence of the fouling.

Another method for detecting a fouled compressor is performance monitoring. Performance monitoring involves obtaining gas turbine data on a routine basis, which, in turn, is compared to baseline data to monitor trends in the performance of the gas turbine. The performance data is obtained by running the unit at a steady base load and recording output, exhaust temperatures, inlet air temperatures, barometric pressure, compressor discharge pressure and temperature, and fuel consumption. The data should be taken carefully with the unit warmed up. If performance analysis indicates compressor fouling, it should be verified by a visual inspection.

The compressor cleaning operation is conducted after turbine shut down (crank-soak cleaning) or while operating (on-line cleaning). A consistent gas turbine water-wash strategy pays for itself many times over in power and efficiency improvement. A crank-soak wash is typically the only means to remove most deposits, including oily or tarry deposits which bind dirt to the blades. Because crank-soak wash cleans the suction (convex) side of the blade, it has the greatest influence on compressor efficiency.

There are no hard and fast rules on when to crank-soak wash because the schedule must be tailored, based on type of atmospheric contaminants, temperature, operational frequency, gas turbine health, and site economics. In the absence of this information, a prudent strategy would be to crank-soak (off-line) wash every two weeks. High concentration of oily deposits and dust will require more frequent crank-soak washing.

On-line washing serves primarily to maintain gas turbine performance between crank-soak washes. The primary effect of on-line washing is to remove deposits on the blade which adhere by impact. Also, dust and dirt are removed on the pressure (concave) side of the blade but not on the suction side, which has a lesser influence on efficiency. For this reason, the use of water for on-line wash is often as effective as a detergent solution. The higher the concentration of oil and tars, the less effective on-line washing will be for improving performance.

In the absence of site-specific information, it would be beneficial to on-line wash with water daily. Use of detergent should be based on testing which demonstrates measurable benefits for the site. Visual inspection of the rinse water is effectively used by some sites to set the wash schedule. If the rinse is mostly clear, the interval can be extended.

FILTER CLASSIFICATION

Filtration systems are optimised to minimise foreign contaminants entering the gas turbine, and are largely based on the operating environment. Seasonal pollutants, rain, ice and snow, sand, dust, local industry exhausts, and other air contaminants must be taken into consideration.

Filters are generally classified by several standard rating methods:

- United States: American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) in standard 52.2: 2007.
- Europe: European Standards EN 779: 2012 and EN 1822: 2009 (Parts 1 through 5).

HEPA filters are generally defined as having an efficiency greater than 85% for particles greater than or equal to a filter's Most Penetrating Particle Size (MPPS). The MPPS for a filter varies, depending upon the media, media velocity, configuration along with other factors, but is primarily between 0.07 microns and 0.2 microns for filters used in gas turbine inlet applications.

CASE STUDIES

Six General Electric Distributed Power LM2X gas turbine sites were investigated. The environment of these sites ranged from continental, relatively clean air, to heavy industrial sites with significant amounts of hydrocarbon aerosols and particulates. The air filter configurations are listed in Table 1. High efficiency filters were installed at two of these sites, as a third stage. Both sites had very poor air quality.

The following sections summarise each case:

US site

This site is an urban area with an interstate highway nearby. There are two filter stages in this system, a pre-filter and the AAF Duracel XL90N. The operator changed the pre-filters at 4,000 hours and primary filters at 8,000 hours. On-line water washing was completed one to three times/week as a proactive measure to minimise off-line washes. Off-line water washing has been performed approximately every three months, equivalent to 2,000 hours of operation. Off-line washing takes about one eight-hour shift, although it usually is performed in conjunction with other work to maximise overall availability. The operational history has shown ~1 MW power loss after the three-month period.

Russian site

The plant has been operating since 2012, in a relatively clean environment and uses only a one stage filter, a static EU8. Still, the HPC rotor blades and stator vanes have rust coloured deposits on the surface. Compressor residue samples should be taken and analysed at a lab to identify the corrosion mechanism. From this, changes to the filtration system and/or wash detergent can be recommended.

Italian site

This site is a small industrial area, but the air is generally clean. The unit is running about half of the year.

There are three filter stages, two pre-filter stages and then the Duracel XL90N. The pre-filter was changed at 7,000 hours because of high dP. Off-line water wash is performed every three to four weeks, or after 700 to 900 hours of operation. The site does not perform any on-line water washing, but conducts off-line water washes frequently to keep the compressor efficiency high.

Belgium site

The plant operates near a refinery. The refinery fumes can be ingested by the gas turbine, causing oil contamination of the filters. Both pre-filters and fine filters are changed every 18 months. Off-line water washing is performed every six months unless the power loss exceeds 1 MW, then an additional off-line wash is performed. On-line washing is generally performed every two days.

China sites

The two China sites investigated are in areas with very poor air quality. The particulate count and size are

Site Location	Environment	Engine Model	Air Filter	Filter Type
US	Continental	LM2500+G4	Static Air Filter; Additional Filter: Pre-Filter, Weather hoods, Guard Filter	Synthetic Panel
Russia	Continental	LM2500+G4	Static Air Filter	Synthetic Panel (F8)
Italy	Industrial (Aerosol, particles)	LM2500+G4	Static Air Filter; Additional Filter: Pre-Filter, Weather hoods, Guard Filter	Synthetic Panel (F8)
Belgium	Continental	LM2500+G4	Static Air Filter; Additional Filter: Pre-Filter, Weather hoods, Guard Filter	Synthetic Panel (F8)
China Site 1	Heavy Industrial (Aerosol, particles)	LM2500+	Static Air Filter: Pre-Filter, Duracel XL90, HEPA	G4, F8. H12
China Site 2	Heavy Industrial (Aerosol, particles)	LM2500+G4	ASC Pulse Filter, HEPA	F8, H12

Table 1: Summary for investigated sites

shown in Figure 2, taken at different times of the year. The particulate count at the size level of 0.3 µm and 0.5 µm make up 99% of the contamination. At this level, the particulates are captured by the second and third stage filters.

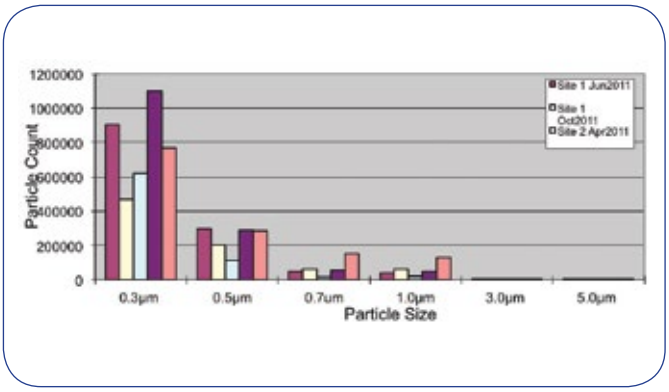


Figure 2: Particle test result at China sites

China site 1

There are three filter stages. The first stage is a G4 pre-filter, the second stage is a Duracel F8, and the third stage is a HEPA H12 filter. The filter change cycles and water wash cycle are shown in Figure 3, for Unit 2 at the site.

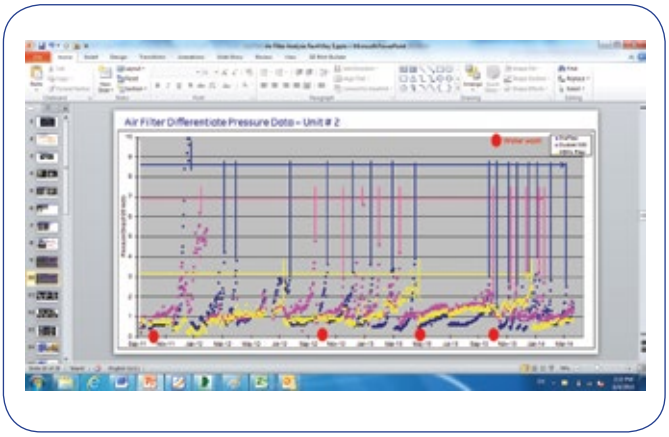


Figure 3: Filter change and water wash data (Unit 2)

The first stage pre-filter change cycle is three to four months from March through October, then typically less than once a month from October through March. The second stage Duracel change cycle is four to eight months (March to October), and from one week to two months (October to March). This is because of poor air quality in the winter months. The third stage HEPA filter change cycle is quite stable, at every six to nine months. Off-line water wash is performed at every 4,000 hours and requires eight to 10 hours to complete.

China site 2

The plant has a pulse filter system, and there are two filter stages. The first stage is an ASC Panel Pak element (F8), and the second stage is a HEPA filter (H12). The filter change cycle and water wash cycles are shown in Figure 4 (three gas turbines on site).

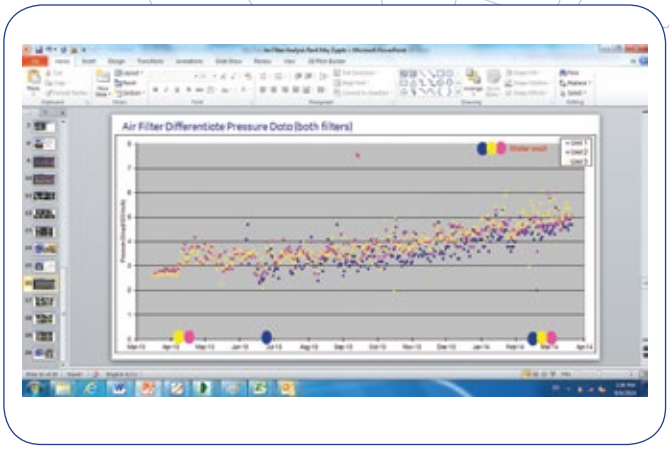


Figure 4: Filter change and water wash data

Both the pulsed filter and HEPA filter have not been changed, and have been running almost one year. Filter pulsing has proved very effective in removing particles. Off-line water wash is performed at every ~4,000 to 5,000 hours. No on-line water washing has been conducted.

FILTER CHANGE CYCLE/ WATER WASH CYCLE ANALYSIS

The filter change cycle and water wash cycle data are summarised in Table 2.

Not surprisingly, better air quality sites do not have to change the pre-filter as often. The filters at China site 2 performed better than those in China site 1 due to the effectiveness of the pulse cleaning mechanism. The water wash cycle, both on- and off-line, at the site with no (H)EPA is more frequent, meaning more downtime at the plant.

CONCLUSIONS

The site analyses showed that (H)EPA filtration results in cleaner compressors, longer cycles between water washing, and subsequently higher compressor efficiency and plant availability.

To illustrate the savings, costs are normalised, and assumptions are based on the site data summarised in this article. It is assumed that the there is a 14% cost adder for (H)EPA filtration, and a negligible power loss due to higher filter differential pressure.

Further, it can be assumed that a 3% efficiency drop occurs linearly over a two-month period (non-(H) EPA) or six-month ((H)EPA). Base natural gas price is US$ 16/MMBtu (Asia) and power sells for US$ 15/MW-hr. Using (H)EPA filtration, the loss of compressor efficiency is at a rate one-third slower than without. For a 32 MW turbine, the net present value is >US$ 550,000 for a base-load machine for one year and US$ 3.7 million over 15 years, as shown in Table 3. That is, a net benefit for (H)EPA filtration. Another

Project Name	Filter Change Cycle			Water Wash Cycle	
	Pre-Filter	Static/Pulse	(H)EPA	Online	Offline
US	5.5 months	11 months	No (H)EPA	1-3 times/ week	every 2-3 months
Russia	No change	No change	No (H)EPA	No	every 2 months
Italy	9.7 months	No change	No (H)EPA	No	every 3-4 weeks: 700-900 hours
Belgium	every 18 months	every 18 months	No (H)EPA	Every 2 days	every 6 months
China Site 1	1 week-4 months	2 - 8 months	6 - 9 months	No	every 5.5 months
China Site 2		every 12 months	every 12 months	No	every 5.5 months

Table 2: Summary for filter change cycle and water wash cycles

US$ 200,000/year could be assumed for increased operating time due to infrequent off-line water washing. (H)EPA filtration yields higher compressor efficiencies over a longer period, saving fuel costs compared to non-(H)EPA filtration systems.

Proper filtration is essential for gas turbine peak performance. Selecting the optimal filters and configuration is based on operating and environmental factors. Improper filtration will degrade turbine performance, including blade erosion, fouling, cooling passage plugging, and corrosion.

These and other factors should be discussed with the OEM turbine manufacturer or filter supplier. Cost-benefit models for specific operating environments can be applied and account for filter purchase price, fuel price, power sale price, maintenance, inspections, wash cycles, power degradation, heat rate increase, pressure loss, labour costs and down-time.

(This article is based on a paper authored by James DiCampli, P E, GE Power and Water; Jack Pan, GE Power and Water; and Mark Arsenault, American Air Filter Ltd, and presented at POWER-GEN Asia 2014.

POWER-GEN Asia 2014, Renewable Energy World Asia 2014, and the newly created POWER-GEN Asia Financial Forum 2014 were held at the Kuala Lumpur Convention Centre, Kuala Lumpur, Malaysia, from 10 to 12 September 2014, as part of the ASEAN Power Week 2014.

POWER-GEN Asia is the region's premier conference and exhibition for the power generation, transmission and distribution industries.

Renewable Energy World Asia is a leading conference and exhibition for the Asian renewable and alternative energy industry.

POWER-GEN Asia Financial Forum is a conference devoted to all aspects of financing of all types of power infrastructure in the ASEAN region.

All three events are organised by PennWell Corporation).

Variable Title	Variable Value	Year	Power loss cashflow	Efficiency raw cashflow	Net Adj annual cashflow
3% efficiency loss to wash		1	$0	$1,269,504	$1,103,917
Fuel MMBtu/hr	330.6	2	$0	$1,269,504	$959,927
MW	35.732	3	$0	$1,269,504	$834,719
Fuel $/MMBtu	16	4	$0	$1,269,504	$725,843
Sell price, $/(MW-hr)	15	5	$0	$1,269,504	$631,168
# years	15	6	$0	$1,269,504	$548,842
rate of return	0.15	7	$0	$1,269,504	$477,254
run time, hr/yr	8000	8	$0	$1,269,504	$415,003
		9	$0	$1,269,504	$360,872
NPV w/o Cost	**$7,423,260**	10	$0	$1,269,504	$313,802
Equipment Cost Adder	-$34,440	11	$0	$1,269,504	$272,871
		12	$0	$1,269,504	$237,279
NPV/3	**$3,694,409.86**	13	$0	$1,269,504	$206,330
		14	$0	$1,269,504	$179,417
		15	$0	$1,269,504	$156,015

Table 3: Fifteen-year return for HEPA filtration, base load

Gas turbine inlet air fogging for humid environments

by Thomas R. Mee III, Mee Industries Inc, USA

Gas turbine inlet air fogging has been used for more than 25 years and has been employed on more than 1300 gas turbines around the world. Fogging consists of spraying very small water droplets into the inlet airflow to cool the air by evaporation. Inlet fogging increases gas turbine power due to the fact that cooler air is denser, so the mass flow of the working fluid increases, and because the compressor is more efficient at lower air temperatures.

Many magazine articles giving user experiences with inlet fogging systems have been published (eg Schwieger, 2008). Operators have also replaced media-type evaporative coolers with fogging systems, which can give more cooling and an improvement in heat rate due to the fact that fog systems impose a negligible pressure drop on the inlet airflow (Ingistov S, Chaker M, 2011). Fog systems also have the added advantage of allowing an operator to control gas turbine output by adding or removing fog nozzle stages, whereas evaporative coolers are either on, providing maximum evaporative cooling, or off, providing no cooling.

Fogging can also be used to provide an additional power increase by intentionally spraying more water than will evaporate in the inlet air - commonly called wet compression, overspray or hifogging. 'Over-spray' water droplets evaporate inside the compressor where they produce an intercooling effect (Hill, 1963). Overspray fogging reduces the work of compression per unit of compressor pressure ratio (Wang and Kahn, 2012), and there is a small increase in the mass flow of the working fluid. Overspray fogging has been shown to produce a significant increase in gas turbine output. Injecting fog at a rate of 1% of the air mass flow will provide about a 5% increase in the output of a heavy industrial gas turbine. A fog flow rate of 1% is enough water to provide about 25° C (45° F) of evaporative cooling in air at normal ambient temperature and pressure so the power boost per unit of water is less for overspray fogging than it is for inlet air fogging. Nevertheless, overspray fogging can produce a considerable power boost and a significant economic benefit.

Overspray fogging, has been successfully applied on hundreds of gas turbines around the world and has been used commercially for nearly 25 years with good results. When done properly, compressor blade erosion - from liquid impaction erosion - is eliminated or minimised to acceptable levels. Several gas turbine original equipment manufacturers offer evaporative cooling and overspray-fogging systems. Power boosts from a combination of fogging and overspray fogging can be nearly as much as the power boost produced by inlet air chillers for a fraction of the capital and operating costs and the return on investment can be better than inlet chillers (Bhargava, 2012).

This article will explore the use of inlet air fogging in humid environments and show techniques for using Typical Meteorological Year data to get accurate estimates of annual output gain, and of the water and electrical consumption of the fog system. The city of Kuala Lumpur, Malaysia is used as an example because it is the location of the 2014 conference and one of the most humid cities in the world.

Misconceptions about humidity levels in humid environments

Many inlet fogging installations are in very humid environments and experience shows they produce significant power gains. Yet there continues to be a misconception that fogging only works well in dry climates.

Relative humidity expresses the amount of atmospheric moisture relative to the amount of moisture that would be present in saturated air at the given temperature. If total moisture content is held constant while temperature is increased, the relative humidity of an air sample will fall. For example, air at 35° C (95° F) and 50% relative humidity has the same total moisture content as air at 23° C (73° F) and 100% relative humidity. High ambient humidity levels do limit the amount of evaporative cooling that can be accomplished, which in turn limits the power boost available. However, on a hot afternoon, it is always possible to do a significant amount of evaporative cooling even at locations with high humidity.

The misconception about evaporative cooling in humid climates may be partly due to the fact that relative humidity is often reported as an average for a given day or month. For example, the Wikipedia article on Kuala Lumpur gives climate data for each month of the year. June is reported to have an average high temperature of 33° C (91° F) and an average low of 23° C (73° F). Humidity is reported as 80%, without saying if it is an average, or the average high, etc.

It is actually quite rare for the relative humidity to be 80% on a hot afternoon. Figure 1 shows the typical Kuala Lumpur climate plotted on a psychrometric chart with coloured boxes showing the typical hours of occurrence for each psychrometric condition. The red dot is at 32° C and 80% relative humidity, which falls outside of the typical range of climatic conditions for Kuala Lumpur. Figure 1 shows that it is sometimes possible to cool by more than 10° C, which would give about a 7% power increase for a typical industrial gas turbine.

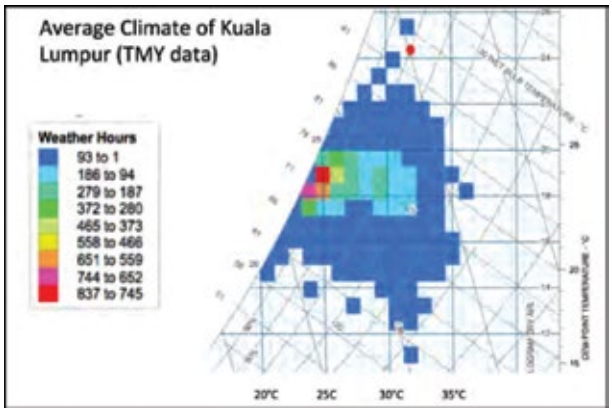


Figure 1: The typical climate of Kuala Lumpur.

The saturation pressure of water vapour increases non-linearly with temperature. Note how the 100% relative humidity curve in Figure 1 increases steeply for small increases in temperature. This means that there can be far more atmospheric water vapour present when air is hotter.

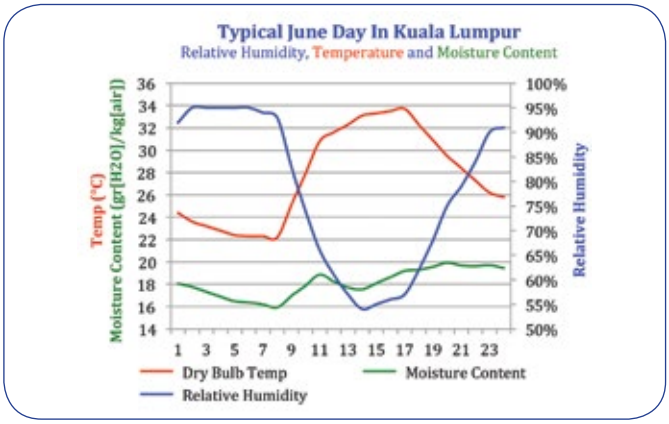


Figure 2: Typical June day in Kuala Lumpur (TMY data).

Total water vapour content does not usually change much over a given day but the steep increase of the saturation curve with increasing temperature, means that much more water can evaporate when the temperature is higher. Therefore, the lowest relative humidity nearly always occurs in the hot afternoon, and the highest relative humidity usually occurs late at night. Figure 2 shows this phenomenon - relative humidity (the blue line) begins to decrease as the temperature (red line) begins to rise. Note that the relative humidity decreased significantly even though total moisture content went up - from 16 gr (water)/kg (air) in the early morning to 20 gr/kg in the late afternoon.

The process of evaporative cooling

Water molecules (H_2O) have a neutral charge because they have an equal number of protons and neutrons. However, the oxygen atom attracts electrons slightly more strongly than the hydrogen atom so there is a slightly negative charge near the oxygen atom and a slightly positive charge near the hydrogen atoms. This means the positive end of one molecule is attracted to the negative end of another molecule giving liquid water a degree of cohesion. The polar nature of water also makes it a strong solvent - it attracts both negative and positive ions.

However, if sufficient heat is added to the fluid - the latent heat of vaporisation - the intermolecular cohesive forces are overcome and individual molecules can escape the surface of the fluid. Evaporation increases with increasing temperature because the kinetic energy of a molecule is proportional to its temperature and more energetic molecules are more likely to have sufficient energy to break the intermolecular bonds and exit the fluid.

When an energetic molecule leaves a liquid, the remaining liquid molecules have lower kinetic energy so the liquid

cools. Water molecules are constantly entering and exiting liquid water surfaces but if the number of molecules leaving and returning reaches equilibrium, the space above the fluid is said to be saturated with vapour (100% relative humidity). When humid air is cooled, the evaporation process reverses. The number of vapour molecules entering the liquid exceeds the number of molecules leaving the liquid and the latent heat is converted back to sensible heat - the heat of condensation.

It is sometimes said that hot air can hold more water vapour but this is a mis-statement because air does not 'hold' vapour. It is just that a hotter liquid has more molecules that possess sufficient kinetic energy to break their intermolecular bonds so more molecules tend to leave the surface.

Intermolecular cohesive forces also cause surface tension. Molecules at the surface have fewer neighbours - no neighbour above - so the charge is spread over fewer connections and they cohere more strongly to their neighbours. Surface tension may play a larger roll in the evaporation process than was previously thought. The heat of vaporisation of substances has been determined empirically and several equations have been developed. However, there has not been consensus on the exact physical processes involved and multipliers were required to make the equations fit experimental results (Garai, 2009).

Garai proposed a model for calculating the heat of vaporisation from first principles, which shows good agreement with experimental results. According to Garai, the energy required to liberate a molecule from a liquid surface is equivalent to the energy required to break the surface tension (Figure 3).

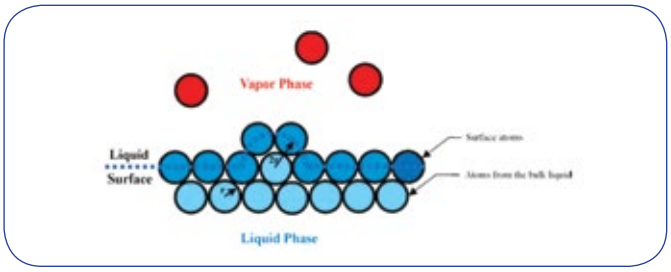


Figure 3: Atom breaking the surface (From Garai, Physical Model for Vaporization).

The relationship between surface tension and the heat of vaporisation is well known. Water, for example, has a high heat of vaporisation and a high surface tension, while ethanol has a low heat of vaporisation and a lower surface tension (Figure 4).

Liquid	Heat of Vaporization	Surface Tension (@ 20°C)
Water	2257 (kJ/kg)	0.73 (N/m)
Ethanol	846 (kJ/kg)	0.02 (N/m)

Figure 4: Heat of vaporisation and surface tension for water and ethanol.

Another recently published study seeks to explain both the heat of vaporisation and the critical point in terms of kinetic energy and surface tension (Mayhew, 2013). Rather than considering only single collisions of particles in a fluid, Mayhew shows that the latent heat of vaporisation can be supplied through the collision, in an infinitesimal instant of time, of all of the neighbouring molecules with the vaporising molecule. This gives the vaporising molecule the energy necessary to break the surface tension of the liquid. Mayhew's theory seems to answer the question of why atoms or molecules on the surface of a liquid tend not to be the ones to evaporate - they have fewer neighbours.

For fog droplet evaporation, the hot air molecules surrounding a fog droplet supply the heat of vaporisation, so the air is cooled as the droplet evaporates. Mass is transferred but energy is conserved, which means there is no change in the enthalpy - or total heat - of the air/vapour mixture. The heat used to vaporise the water droplet is 'latent' in the air/vapour mixture while the 'sensible' heat of the air is reduced.

Textbook explanations of evaporation seem likely to change in the near future. Nevertheless, we can say in simple terms that evaporation requires energy. If rapidly vibrating air molecules supply that energy, the air molecules lose some of their kinetic energy so the air cools.

Sources of atmospheric water vapour

Atmospheric water vapour comes mostly from natural sources - evaporation from water bodies, transpiration from plants, evaporation from soil, volcanic eruptions, sublimation from ice and snow, respiration of animals, etc. Most of the water vapour in the atmosphere comes from evaporation from warm ocean surfaces in subtropical regions (Figure 5) that are mostly cloud-free so they are quickly heated by in coming solar radiation. The easterly trade winds in both hemispheres push air masses both westward and towards the equator. The air masses pick up large amounts of moisture from the hot ocean surface causing large portions of the subtropical oceans to lose more water from evaporation than they gain from precipitation - the yellow areas in Figure 5. Evaporation rates from these warm ocean surfaces can exceed 5 mm per day.

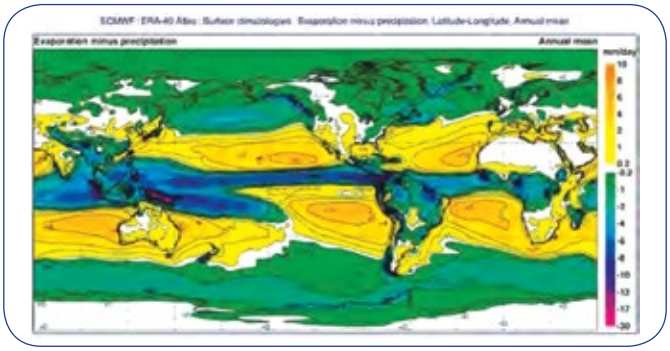


Figure 5: Annual mean evaporation minus precipitation (NASA figure).

Air masses from both hemispheres meet at the equator in the inter-tropical convergence zone (ITCZ) where convergence, convection, and the fact that humid air is less dense than dry air, cause the hot moist air to rise. The water vapour condenses to form clouds and the moisture rains out - the blue and purple areas - causing equatorial regions to have far more precipitation than evaporation.

Trees and plants also add significant amounts of water vapour to the atmosphere. They act like evaporative coolers. They remove liquid water from the soil (by osmosis) lift the water to canopy level (by capillary action), and emit it to the atmosphere (by evaporation) through microscopic pores called stomata. The evaporation of water from plant stomata is called transpiration.

Transpiration increases near-ground humidity and removes heat from plant leaves, which in turn keeps the surrounding air temperature below what it would otherwise be.

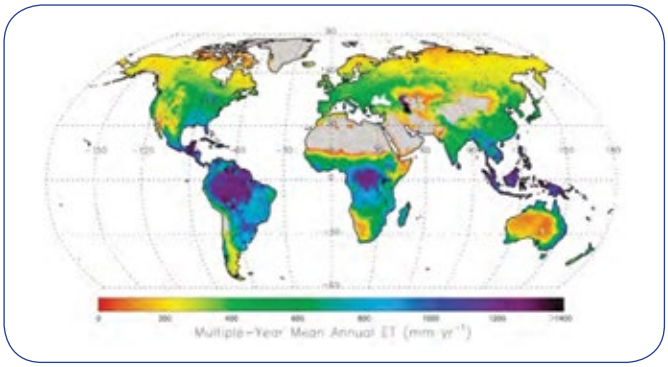


Figure 6: Mean annual evapo-transpiration (1983-2006) in mm of water per year (Zhang et al, 2010).

Figure 6 shows evaporation and transpiration from land surfaces, called evapo-transpiration. Note the higher rates in areas with rainforests and dense vegetation - dark blue areas - and the near zero evaporation rates in desert areas. Transpiration is probably responsible for much of the near-ground atmospheric water vapour in tropical rainforest environments with dense vegetation.

Transpiration is difficult to measure in natural environments. Experiments performed by injecting radioactive dyes into the sapwood of tropical trees - to measure sap flow rates - yielded estimates that a large tropical tree in the Venezuelan rainforests emits as much as 1.2 m^3 of water per day (Jordan & Kline, 1977) - hence the foggy rainforests of Malaysia.

It is interesting to note that just 10 typical inlet-air fogging nozzles can atomise and evaporate 1.2 m^3 of water in a 12-hour day. A typical fog system for a large industrial turbine can have more than 1000 fog nozzles giving it the equivalent evaporation of 100 large tropical trees.

Transpiration clouds regularly form over tropical forests. Figure 7 shows popcorn-like clouds over the Amazon basin, taken by NASA's Agua satellite (NASA image, 2009).

Figure 7: Transpiration clouds over the Amazon rainforest.

These clouds tend to form during the dry season as trees pump water from the ground and transpire it to the air above.

It has been estimated that 32 x 1015 kilograms of water are transpired by equatorial rainforests each year (Schneider & Segan). Agricultural areas also produce significant amounts of water vapour. A hectare of well-irrigated corn can transpire 37m^3 of water per day (14,000 gal/acre per day) (NASA website).

The global average ratio of transpiration from plants (T) to evaporation from other surfaces (E) - the T/E ratio - seems to be unknown and is a major source of uncertainty for global climate models because water vapour is a strong greenhouse gas and far more plentiful than anthropogenic greenhouse gases such as carbon dioxide or methane. Methods for measuring the T/E ratio using the ratio of water isotopes found in precipitation are based on the observation that evaporation from ground and open water surfaces favours lighter isotopes of water, while transpiration favors heavier isotopes. Isotope studies show that transpiration could account for more than 50% of evaporation from the continental areas of the planet (Sutanto et al, 2014).

The photosynthetic process uses as little as 1% of the total water that moves through a typical plant. An average plant must transpire between 200 and 500 grams of water in order to create 1 gram of biomass (Schneider & Kay, 1995). The ratio of water transpired to biomass produced by young plants was found to be 100 grams of water to add one gram of mass (author's experiment). However, one would expect much higher numbers for mature plants and trees.

Human activity also produces water vapour because water vapour is a product of combustion of fossil fuels. Approximately 8% of gas turbine exhaust is water vapour. Likewise, wildfires can liberate significant amounts of water vapour when plant material burns. Some of this vapour comes from liquid water trapped inside the plant material but a large portion of the vapour comes from the combustion of cellulose. Plants synthesise cellulose from atmospheric CO_2, water and sunlight. The formula

for cellulose is $C_6H_{10}O_5$, so combusting one molecule of cellulose produces 5 molecules of H_2O. Note the bright-white water droplet cloud that formed above the smoke plume in Figure 8. Pyrocumulus clouds can get large enough to form lightning which can start secondary wildfires.

Figure 8: A pryrocumulus cloud that formed during a wildfire near Los Angeles, California, in 2008 (photograph by the author).

Humid tropical environments

In tropical areas with dense vegetation, like Malaysia, transpiration adds significant amounts of near-ground atmospheric water vapour. When the sun rises in the morning, the stomata of plants open to allow the gas exchange necessary for photosynthesis, and water is evaporated from countless microscopic stomata cavities. This effect may be discernible in Figure 2, where the total moisture content rises quickly after sunrise. The effect of transpiration is also evident from Figures 6 and 8.

Air near wetted surfaces, including inside the stomata of vegetation, can become quickly saturated on a hot day. Atmospheric mixing - due to convective currents formed by the uneven solar heating of the planetary surface - and the fact that humid air is lighter than drier air of the same temperature, along with the much slower process of vapour diffusion, mixes near-ground water vapour with drier air, thereby making it possible to evaporate more water.

Water vapour is lifted high above the ground, where it condenses to form clouds. Mixing means that there is most often not sufficient time in one day for the entire near-ground atmosphere to become fully saturated while at an elevated temperature. When the sun sets, long-wave radiation to space causes surfaces exposed to the night sky to quickly cool. Water is a strong greenhouse gas, so humid environments cool slower at night than dry environments. Nevertheless, if the temperature of exposed surfaces falls below the dew point of the surrounding air, water vapour will condense back onto cold surfaces and/or form low-lying clouds or ground fog. The dew point temperature is the temperature at which condensation will begin to form if moist air is cooled.

Convective mixing and night-time cooling place an effective upper limit on the amount of water vapour that can be present, even in environments with abundant surface water and dense vegetation. Near-ground water vapour concentrations of more than about 2.5% are rare in tropical environments.

Humid temperate zones

High day-time humidity levels are not limited to tropical environments. Continental areas in temperate zones can become quite humid in the summer due to evapo-transpiration.

In the summer of 2011, a slow-moving high-pressure zone over the central US in the month of July created a heat wave with record high moisture levels. A higher dew point temperature means higher moisture content. Dew point temperatures of 32° C (90° F) were recorded in north-central US, close to the Canadian border, in the middle of an area of intense agricultural activity, and hundreds of kilometers from any large bodies of water (Burt 2011).

Reports of pooling water near the weather station might explain this very high dew point temperature, so it may not be representative of the wider climatology. Nevertheless, very high dew points were recorded throughout the region during that heat wave. The dry bulb temperature at the time was 38° C (100° F) so the total moisture content was about 3%, which is probably higher than one would find in a tropical area.

Humid deserts

The highest dew point temperatures on Earth actually occur in arid areas. Land masses on the shores of the Red Sea, the Gulf of Aden and the Persian Gulf, can have summertime temperatures that can reach above 50° C. The relatively shallow seas in the area heat rapidly and can have sea surface temperatures of as high as 35° C (Nandkeolyar, 2013). There is little vegetative growth in these areas, so ground-level moisture comes primarily from evaporation off the surfaces of the nearby seas rather than from transpiration.

The highest dew point temperature on record occurred in July of 2003 at Dhahran, Saudi Arabia which reported a dew point of 35° C (95° F) with a coincident dry bulb of 42° F (108° F) (Burt 2004). These conditions equate to an atmospheric water vapour content of 3.3%.

Such records should not be taken as fact since numerous human-caused and natural factors can cause the microclimate around a particular weather station to result in readings that are not representative of the climatology of a region (for examples see www.surfacestations.org).

GT inlet air cooling in humid environments

Extremes are interesting but they do not tell us if evaporative cooling is beneficial in a given environment. For example, the average dew point on the day the record was set in Dhahran was just 16° C (61° F) even though the dew point reached 35° C (95° F) (www.weatherunderground.org). At 15:00, when the record was set, it was still possible to do 6° C (10.8° F) of evaporative cooling, which is more cooling than one might get in a tropical or temperate environment on a much cooler day. At 15:00 on the day after the record dew point temperature was recorded, it was possible to do 15° C (27° F) of cooling.

It turns out that evaporative cooling can be quite beneficial for gas turbines located in Dhahran, Saudi Arabia. There are successful fog system installations just 30 km away, across the causeway on the island of Bahrain and even on an offshore oil platform in the Persian Gulf.

The wet bulb temperature is the temperature reached if water is evaporated to reach saturation in non-saturated air. The potential for evaporative cooling is defined as the dry-bulb temperature minus the wet-bulb temperature - often called the wet bulb depression. As water droplets evaporate, the air is cooled due to the latent heat of vaporisation but evaporation stops when the wet bulb temperature is reached.

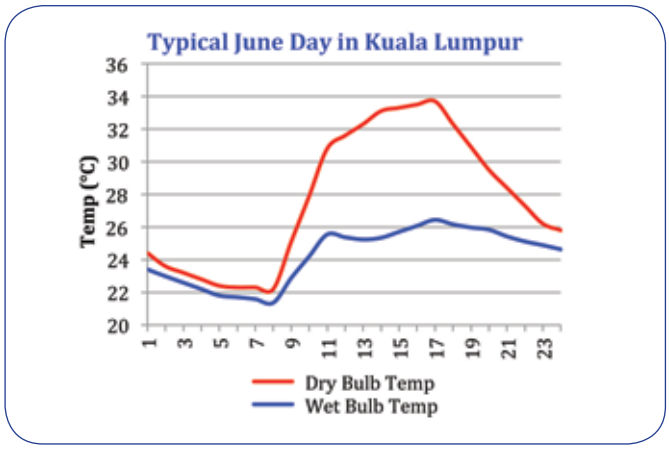


Figure 9: Wet bulb depression in Kuala Lumpur for July 20, 2014.

Figure 9 shows the wet bulb depression for Kuala Lumpur on the same typical day as Figure 2. The wet bulb depression is about 8° C (14° F) at 16:30 hours. The output increase for a typical industrial gas turbine with 8° C of cooling is about 6%. In a desert environment, power boosts of more than 20% are possible but a 6% power boost still gives a significant economic benefit due to the low capital and operating costs of inlet fog systems.

Typical Meteorological Year data sets

Typical Meteorological Year (TMY) data is a collection of meteorological data for specific locations around the world, that gives hourly data for a 'typical' year. The data sets were developed to compare different methods of indoor climate control for buildings. They are also used for making calculations for renewable energy conversion systems such as solar photovoltaic installations. TMY data sets are not suitable for sizing equipment because they represent typical climate conditions, not extremes. The data sets were constructed using 30 years of measured weather data. The hourly weather data used are actual measured data, interpolated or in-filled using data from nearby stations if actual data was not available.

Sandia National Laboratories produced the first TMY data sets for the United States in 1978 (S Wilcox and W Marion, 2008). Typical or representative months were selected using algorithms developed at Sandia (Hall et al, 1978). These 'typical' months are then concatenated to form a typical meteorological year. The most up-to-date TMY data set (TMY3) was compiled by the US Department of Energy's National Renewable Energy Laboratory and is available on the Internet.

Using TMY Data to estimate annual evaporative cooling potential

TMY data is well-suited for making analyses of the economic benefits of inlet air fogging for gas turbines because they represent a typical year and are therefore more likely to give a reasonably accurate picture of the average benefit that can be expected over a period of many years. Climate is highly variable on daily and annual scales so no future year will be exactly the same as a typical year. However, TMY data does allow a reasonably accurate estimation of what can be expected from an inlet air fogging system for a typical year in the future.

TMY data can be used to construct a chart showing Evaporative Cooling Degree Hours (ECDH) for a given power plant site. Figure 10 shows such a chart for Kuala Lumpur - based on the work of Ross Petersen, Mee Industries Inc. A similar method was used to show evaporative cooling potential for different cities around the world (Chaker & Homji, 2002).

Figure 10 shows the degree-hours of cooling possible for each hour of the day, for each month of the year. The amount of cooling is calculated by converting the TMY dry bulb and dew point data to wet bulb, then subtracting the wet bulb from the dry bulb to get potential cooling. This process is done for every hour of the year then presented as degree-cooling hours for each hour of the day for each month.

In the example shown, degree-hours of potential cooling are not calculated if the ambient temperature was below 27° C (80° F), the assumption being that a power boost

may not be required when the temperature is below 80 °F. Cooling is also not calculated for cooled-to temperatures below 13° C (55° F) to ensure there will be no icing at the compressor inlet due to adiabatic cooling - although it is never possible to cool to such a low temperature in Kuala Lumpur. These assumptions can be changed to allow users to evaluate different scenarios.

From the chart, we can see that the month of June has the most potential for evaporative cooling - yellow highlight - and it is possible to do more than 15,000 degree-hours of evaporative cooling in a typical year.

Estimating gas turbine and fog system performance using TMY data

Evaporative Cooling Degree Hours, derived from TMY data, are combined with data characterising the response of a particular gas turbine to changes in inlet air temperature and the water and power consumption of the fogging system. These calculations are done for each hour of the typical meteorological year.

Annual Evaporative Cooling Degree-Hours for Kuala Lumpur Malaysia

Hour -->	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	Totals
January	0.0	3.7	87.2	135.1	163.3	187.7	212.6	191.9	170.2	149.0	122.6	1423
February	0.0	6.1	78.3	129.4	150.1	169.8	189.7	167.3	145.1	119.5	99.8	1255
March	1.8	21.5	78.9	117.7	142.6	165.5	188.9	173.2	156.1	132.6	107.4	1286
April	4.3	45.4	99.2	136.9	156.4	182.5	206.6	180.5	154.1	118.4	98.9	1383
May	3.9	38.3	90.1	123.6	140.9	155.8	169.1	158.4	145.9	131.0	113.2	1270
June	3.3	31.4	97.1	142.4	158.0	172.3	191.8	186.7	180.4	174.6	149.9	1488
July	7.8	15.6	93.9	128.5	141.1	150.5	157.4	160.5	160.0	156.8	131.6	1304
August	6.2	15.5	75.5	112.9	139.0	159.4	179.3	166.3	153.6	136.4	112.6	1257
September	0.0	15.7	91.9	140.5	157.9	174.5	198.0	172.7	148.5	126.7	108.5	1327
October	0.0	0.0	65.5	114.2	137.1	158.0	176.7	163.9	146.4	133.3	106.2	1201
November	0.0	14.8	77.7	111.4	127.4	135.5	148.7	139.9	129.8	116.0	94.7	1096
December	2.7	3.7	56.8	100.9	117.8	138.7	156.4	144.2	129.9	116.8	90.0	1058
Totals ...	30	212	992	1493	1732	1950	2167	2006	1820	1611	1335	15,348

Figure 10: ECDH chart for Kuala Lumpur constructed from TMY3 data.

The fog system water and electrical power consumption are calculated based on the amount of cooling and the air-mass flow of the gas turbine. Figure 11 shows the results for evaporative cooling on a GE-9EA gas turbine in Kuala Lumpur between 8:00 and 18:00 for every day of the year. The power boost produced by the fog system is 12,570 MW-hours. The fog system consumed 53,719 kW/hr of electricity - just 0.4% of the extra power produced - and it consumed 9,946 m^3 of demin water.

It is important to keep in mind that the heat rate is also improved. Similar calculations can be performed for overspray fogging.

Concluding remarks

This article sought to illuminate facts showing that evaporative cooling with inlet air fogging can be effective and economically beneficial in humid environments. The sources and sinks of near-ground water vapour were discussed. A computational tool that allows gas turbine operators to predict the benefits of inlet fogging using Typical Meteorological Year data sets was reintroduced. Gas turbine operators can use this information to make fairly accurate calculations of return-on-investment (ROI) for a fog system. Further work is underway to develop web-based code that will allow gas turbine operators to use TMY data to quickly compute ROIs for their particular circumstances.

References

Ingistov S, Chaker M: 'Upgrade of the Intake Air Cooling System for a Heavy-Duty Industrial Gas Turbine', Proceedings of ASME Turbo Expo 2011, June 6-10, 2011, GT2011-45398.

Annual Evaporative Cooling Degree-Hours for Kuala Lumpur Malaysia

Hour	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Totals
8:00	0	0	2	4	4	3	8	6	0	0	0	3	30
9:00	4	6	22	45	38	31	16	15	16	0	15	4	212
10:00	87	78	79	99	90	97	94	75	92	65	78	57	992
11:00	135	129	118	137	124	142	128	113	140	114	111	101	1493
12:00	163	150	143	156	141	158	141	139	158	137	127	118	1732
13:00	188	170	166	182	156	172	151	159	174	158	135	139	1950
14:00	213	190	189	207	169	192	157	179	190	177	149	156	2167
15:00	192	167	173	180	158	187	161	166	173	164	140	144	2006
16:00	170	145	156	154	146	180	160	154	148	146	130	130	1820
17:00	149	120	133	118	131	175	157	136	127	133	116	117	1611
18:00	123	100	107	99	113	150	132	113	109	106	95	90	1335
Totals	1,423	1,255	1,286	1,383	1,270	1,488	1,304	1,257	1,327	1,201	1,096	1,058	15,348

GT Output (MWhrs)	1,166	1,028	1,053	1,133	1,040	1,219	1,068	1,029	1,087	984	898	866	12,570
Fog Water (m3)	922	813	833	896	823	964	845	814	860	778	710	686	9,946
Fog Power (kW)	4,982	4,393	4,502	4,841	4,446	5,208	4,563	4,398	4,644	4,204	3,836	3,703	53,719

Figure 11: Performance of a fog cooled GE-9EA gas turbine in Kuala Lumpur.

Schwiger R: 'To fog or not to fog: What is the answer?', Combined Cycle Journal, Third Quarter, 2008.

Hill P G: 'Aerodynamic and Themordynamic Effects of Coolant Injection on Axial Compressors', Aeronautical Quarterly, November1963.

Wang T and Khan J R: 'DISCUSSION OF SOME MYTHS/ FEATURES ASSOCIATED WITH GAS TURBINE INLET FOGGING AND WET COMPRESSION', Proceedings of ASME Turbo Expo 2012 GT2012 June 11-15, 2012, Copenhagen, Denmark.

Bhargava R K, Branchini L, Melino F, Peretto A: 'AVAILABLE AND FUTURE GAS TURBINE POWER AUGMENTATION TECHNOLOGIES: TECHNO-ECONOMIC ANALYSIS IN SELECTED CLIMATIC CONDITIONS', Proceedings of ASME Turbo Expo 2012 GT2012 June 11-15, 2012, Copenhagen, Denmark.

Garai Jozsef: 'Physical Model for Vaporization'. Fluid Phase Equilibria, Volume 283, Issue 1-2, Pages 89-92.

Mayhew K: 'Latent heat and critical temperature: A unique perspective', Physics Essays, Volume 26: Pages 604-611, 2013.

NASA image, NASA & European Centre for Medium-Range Weather Forecasts (ECMWF). This photo is in the public domain because it was created by NASA.

Ke Zhang, John S Kimball, Ramakrishna R Nemani, Steven W Running: 'A continuous satellite derived global record of land surface evapotranspiration from 1983 to 2006', WATER RESOURCES RESEARCH, VOL 46, W09522, doi:10.1029/2009WR008800, 2010.

NASA Earth Observatory website; A Multi-Phased Journey. earthobservatory.nasa.gov/Features/Water/page2.php

Carl F Jordan and Jerry R Kline: 'Transpiration of Trees in a Tropical Rainforest', Journal of Applied Ecology (1977) 14, 853-860.

Sutanto S J, B van den Hurk, G Hoðmann, J Wenninger, P A Dirmeyer, S I Seneviratne, T Röckmann, K E Trenberth, and E M Blyth: 'HESS Opinions: A perspective on different approaches to determine the contribution of transpiration to the surface moisture fluxes', Hydrology and Earth System Sciences Discussions, 11, 2583–2612, 2014.

Scott Jasechko, Zachary D Sharp, John J Gibson, S Jean Birks, Yi Yi and Peter J Fawcett: 'Terrestrial water fluxes dominated by transpiration', Nature 496, 347–350 (18 April 2013).

Neha Nandkeolyar, Mini Raman, G Sandhya Kiran, and Ajai: 'Comparative Analysis of Sea Surface Temperature Pattern in the Eastern and Western Gulfs of Arabian Sea and the Red Sea in Recent Past Using Satellite Data', International Journal of Oceanography, Volume 2013 (2013), Article ID 501602, http://www.hindawi.com/journals/ijocean/2013/501602/

Schneider E D and Sagan Dorion: 'Into the Cool: Energy flow, Thermodynamics and Life', University of Chicago Press, 2005, page 222.

Schneider E D and Kay J J, 1995: 'Order from Disorder: The Thermodynamics of Complexity in Biology', in Michael P Murphy, Luke A J O'Neill (ed) 'What is Life: The Next Fifty Years. Reflections on the Future of Biology', Cambridge University Press, pp 161-172.

Burt C, 2011: Record Dew Point Temperatures. http://www.wunderground.com/blog/weatherhistorian/record-dew-point-temperatures.

NASA image; courtesy Jeff Schmaltz, MODIS Rapid!Response at NASA GSFC. http://earthobservatory.nasa.gov/IOTD/view.php?id=39936.

Burt Christopher C (2004): 'Extreme Weather, a Guide and Record Book, ISBN 0-393-32658-6 (pbk).

Wilcox S and Marion W, 2008: 'Users Manual for TMY Data Sets, NREL/TP-581-43156
Available at: http://www.nrel.gov/docs/fy08osti/43156.pdf

Hall I, Prairie R, Anderson H, Boes E (1978): 'Generation of Typical Meteorological Years for 26 SOLMET Stations', SAND78-1601, Sandia National Laboratories, Albuquerque, NM, USA.

Mustapha Chaker, Cyrus B Meher-Homji (2002): 'Inlet Fogging of gas turbine engines: Climatic Analysis of Gas Turbine Evaporative Cooling Potential of International Locations', ASME paper 2002 - GT-30559, ASME Turbo Expo, June 3-6, 2002, Amsterdam, The Netherlands.

(This article is based on a paper authored and presented by Thomas R. Mee III, Mee Industries Inc, USA, at POWER-GEN Asia 2014.

POWER-GEN Asia 2014, Renewable Energy World Asia 2014, and the newly created POWER-GEN Asia Financial Forum 2014 were held at the Kuala Lumpur Convention Centre, Kuala Lumpur, Malaysia, from 10 to 12 September 2014, as part of the ASEAN Power Week 2014.

POWER-GEN Asia is the region's premier conference and exhibition for the power generation, transmission and distribution industries.

Renewable Energy World Asia is a leading conference and exhibition for the Asian renewable and alternative energy industry.

POWER-GEN Asia Financial Forum is a conference devoted to all aspects of financing of all types of power infrastructure in the ASEAN region.

All three events are organised by PennWell Corporation).

Understanding Electromagnetic Interference and Electromagnetic Compatibility

by ChunSoong Wong, Business Field Support, Rohde & Schwarz (Australia) Pty Ltd

The knowledge will help to improve product evaluation.

Figure 1: An Audi subjected to automotive EMC testing in a chamber located in Ingolstadt, Germany.

Introduction

The discovery of electricity contributed to the impressive industrial revolution and the modernisation of civilisation. Soon, every household started to fill up with electrical appliances for everyday use. We then realised that these appliances generate Electromagnetic Interference (EMI) that could affect one another. Most importantly, our safety and health could also be at stake. Hence, regulations were defined to ensure products meet EMI and Electromagnetic Compatibility (EMC) standards to minimise their emissions and susceptibility. EMI/EMC tests became one of the most crucial product evaluation steps and often determined if a product could be put on shelves.

For decades, spectrum analysis has been used for EMI/EMC testing. Test instruments scan energy levels in different frequencies making sure they do not exceed the limits defined by the standards. To ensure measurement accuracy, test labs with extensive and elaborative shielding chambers are required. Figure 1 shows an Audi RS7 subjected to automotive EMC testing in a chamber located in Ingolstadt, Germany. Since not all companies can afford their own certified EMC labs, they often test their products in third-party test houses. Therefore, the luxury of constantly evaluating a product's EMI performance along the development line is not available. Instead, there is the need to wait until it is close to the final product before sending it to the test lab. This, however, becomes frustrating when the product does not meet the standards and has to be modified. The cost of such modifications can be relatively expensive if the emissions issue lies in the core design. Also, the modified product still needs to go through the test again. Figure 2 provides a good idea of the cost for design modifications in different phases of a typical product roll-out cycle.

Engineers are constantly looking for tools to help them in cost saving and improving the design process. Of course, spectrum analysers should be able to perform similar measurements with accuracy. However, they are still considerably expensive to be on every engineers' bench and do not provide good timing information to help in identifying EMI sources. Luckily, one of the commonly used tools in the lab could be the answer to this - the oscilloscope.

Oscilloscope for EMI analysis

The application of Fast Fourier Transform (FFT) to extract frequency components from time domain traces is not new. In the early digital oscilloscope, the FFT function is

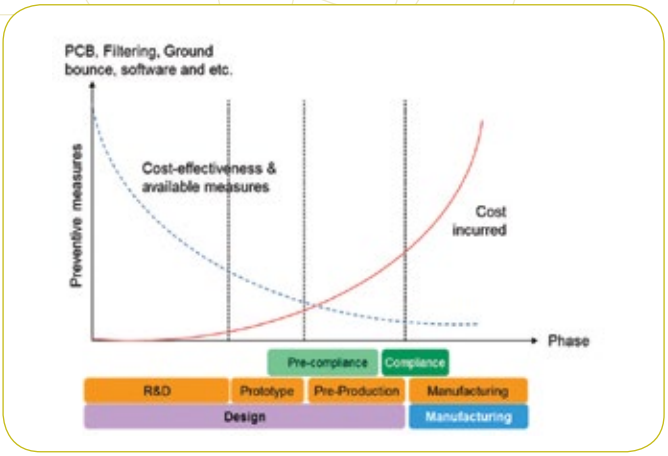


Figure 2: The potential correction cost incurred goes up and the available measures to rectify emissions problems become limited as the product progresses further in the development stage

already available to offer a spectrum perspective of the signal. Limited by computing power, the slow calculation and visualisation caused engineers to shun the feature. Thanks to Moore's Law, processing power is now available in our very own smart phone. The modern oscilloscope is now equipped with powerful computing power, enabling complex FFT analyses. This revisited capability provides access to both time and spectrum domains simultaneously, allowing the user to correlate time and spectral events. Being a more readily available tool on engineers' desks, oscilloscopes enable debugging of EMI problems at the R&D stage, thereby increasing the likelihood of a successful compliance test significantly.

Some modern oscilloscopes have added a spectrum analysis channel to enable such spectrum analyses. Since spectrum and time domain analyses capture signals differently, aligning them takes a toll on the responsiveness of the scope. In EMI debugging, faults can occur randomly and the ability to capture them will depend on how quick the instrument is. For this, modern oscilloscopes such as Rohde & Schwarz's RTO, takes a different approach by implementing hardware FFT analysis in the ASIC chip. This allows time domain waveforms to be quickly transformed into their spectral components while keeping the time-spectrum coherence, as shown in Figure 3.

Figure 3: An emission caused by a rare glitch that happens in the clock signal (Top: clock signal in time. Centre: zoomed in trace where glitch occurred. Bottom: the spectrum). The glitch causes a broad spectral spread as opposed to the repeating harmonics from the clock signal.

To reduce spectral spread caused by the time samples' edge discontinuity in FFT, the signal usually passes through a filter. However, signal anomalies that happen at the edge of a time domain segment, if attenuated by the filter, limit the instrument's chances to observe faults, as shown in the top image of Figure 4. One method to overcome this is by having multiple overlapping FFT capabilities. The concept is basically breaking down the time captures into different overlapping time segments, to obtain multiple FFTs. The overlapped segments allow more chances for the filter-suppressed edge anomalies to be seen, as shown in the lower part of Figure 4. This requires a powerful FFT computation and a dedicated HW FFT definitely helps. Now that more FFTs are being processed and displayed, it will be really helpful to have a colour grading capability to help us differentiate frequent and rare spectral events, as shown in Figure 6.

Near field probing

In EMI/EMC, there are radiated and conducted emission tests, depending on the product design and classification. In radiated emission tests, a far-field antenna is used in a chamber to pick up the electromagnetic field generated from the device under test (DUT). In a conducted emission test, a transducer (ie current clamp) is used to measure

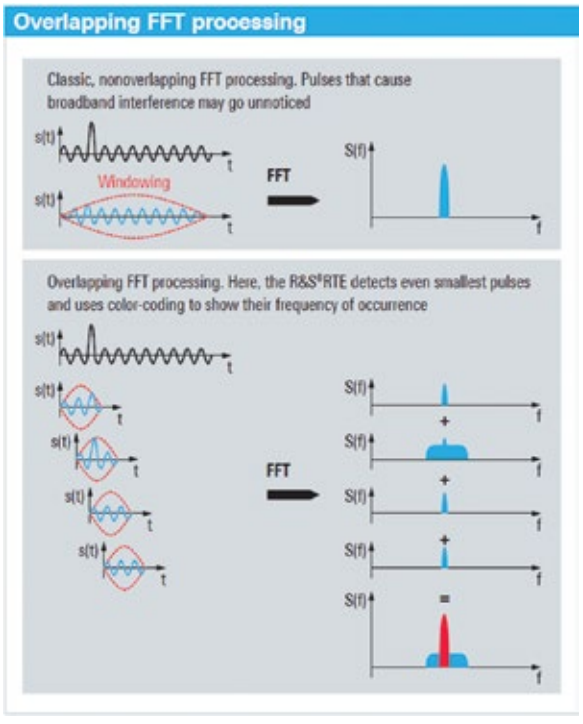

Overlapping FFT processing
Classic, nonoverlapping FFT processing. Pulses that cause broadband interference may go unnoticed
s(t)
Windowing
FFT
S(f)
Overlapping FFT processing. Here, the R&S®RTE detects even smallest pulses and uses color-coding to show their frequency of occurrence

Figure 4: Single FFT windowing filter will attenuate spurious bursts happening at the edge of acquisitions. Multiple overlapping FFTs will minimise the effect and provide more chances to observe the error.

noise caused by the DUT. Both give a macro view on the emission profile and compare against EMC standards. What engineers would really like to know is the location of the source of emission in the DUT. This is because fixing issues at the component level is cheaper than the need to increase the shielding capability of the DUT.

The near field probe, magnetic or electric, has proven to be useful in such circumstances. Since these probes can only sense electric and magnetic fields in close proximity, the user can move the probe in different locations of the DUT to sense which area has the worst emission, as shown in Figure 5. Although what is seen in the near field does not directly equal the far field observation, if not managed well in design, these near field effects manifest and later cause failure in far field testing.

Near field-testing is not new and has been helpful when paired with the spectrum analyser in EMI analysis. The only drawback is that the spectrum analyser's sweep frequency scanning mechanism may take up four to five seconds to measure a spectrum span from 9 kHz up to 30 MHz. The probe will need to stay in the same location for the scan to be completed. The slow sweep also means that random spurious events will take longer to be detected and if the probe is not at the right place at the right time, chances are the anomalies are missed. A real-time spectrum analyser and a real time test receiver using the FFT concept are then introduced to handle such situations.

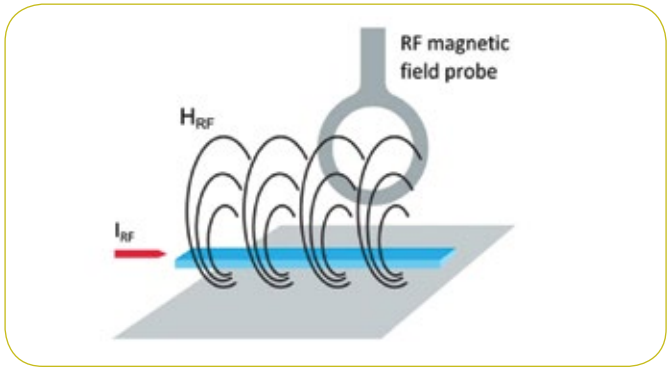


Figure 5: Magnetic near field probe locating emission source radiated from a DUT.

Advanced FFT capabilities

Modern oscilloscopes that are already equipped with fast FFT capability can play a cost-effective role here in performing similar emission source detection using near field probes. As good as it may sound, oscilloscopes may never replace a real-time spectrum analyser or test receiver as it does not have the sensitivity of the narrow-band detector or the noise floor provided by such precision tools. Moreover, oscilloscopes do not have quasi-peak detectors that are required for EMI/EMC compliance testing. It can play the role of an economical reference checking tool, which allows the user to identify the emission frequency and energy level. Changes made to rectify these emissions can also be checked to ensure they are effective and correlate to a proper compliance report.

Additional enhancement of the analysis capability, such as gated FFTs, allows the user to select a portion of the time domain waveform segment to transform form into its spectrum plot. This is another advantage of FFT where multiple parallel processing can be done over the same acquired waveform, which is impossible for a spectrum

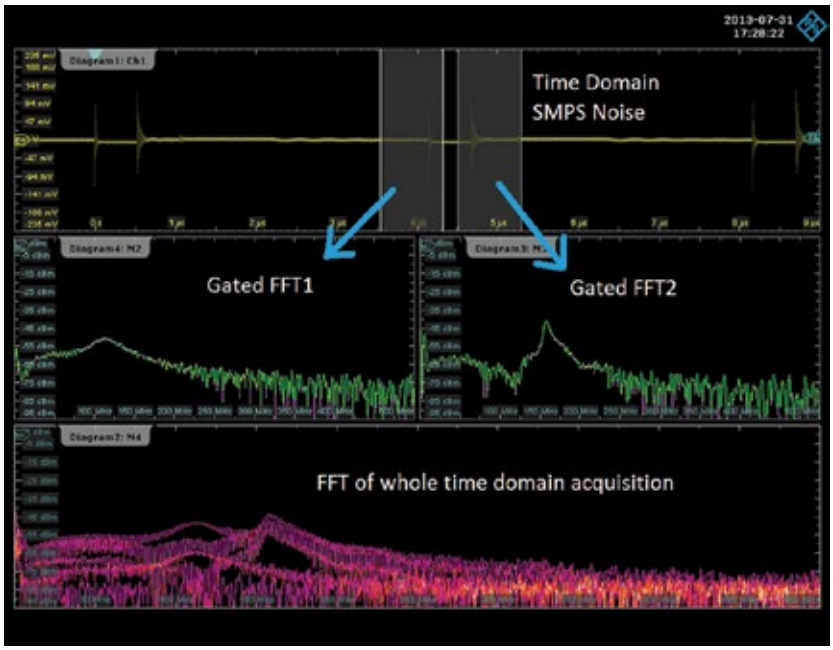


Figure 6: Gated FFTs allow analysis of the selected waveform segment to be compared to another segment in the same acquisition. (Top: Time domain waveform from SMPS. Middle Left: FFT 1 from segment on left. Middle Right: FFT 2 from segment on right. Bottom: FFT of full time domain acquisition). This gives the user a better understanding of their signal behaviour.

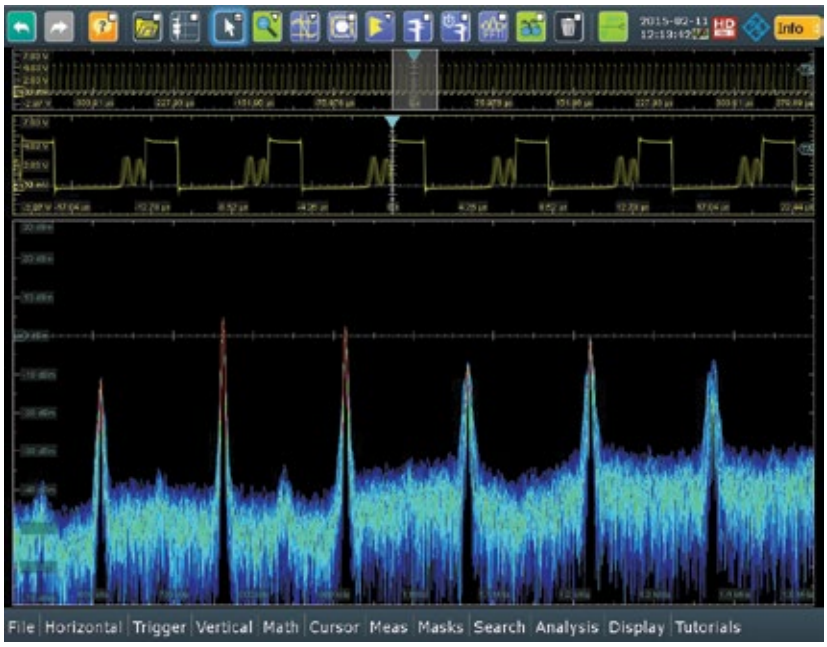


Figure 7: The mask function of the R&S RTO allows detection of sporadic emissions. (Top: Time domain capture. Bottom: Spectrum analysis with mask test mimicking the EMI Limit test with envelope for peak detection).

Figure 8: The R&S RTO, with near field probe showing both the time domain and spectrum domain captured simultaneously, could be the answer for EMI/EMC product evaluation.

analyser. It allows the user to compare FFTs of two or more different timing segments to understand the signal behaviour, as shown in Figure 6.

To be even more effective, features were developed to trigger on FFT events. The mask test which is very useful especially in detecting if a spectrum exceeds a certain signal level can be set up to mimic limit line testing defined by EMI/EMC standards. It can also be used to capture spurious anomalies by detecting if the FFT violates a certain area of the signal diagram, and thus speed up the debugging progress.

Summary

To summarise, modern oscilloscopes today, such as the R&S RTO and R&S RTE oscilloscopes, featuring powerful FFT signal processing, high input sensitivity and extensive acquisition and analysis capabilities, are valuable tools for developers who need to perform EMI debugging on electronic circuits. Using overlapping FFT processing and colour-coded spectral displays, the oscilloscopes provide an overview of the frequency of occurrence of spectral components in the acquired signals, allowing fast identification of EMI sources. Since the FFT function is controlled similarly as in spectrum analysers, users can easily navigate in the frequency domain without having to worry about the time domain settings.

REFERENCES

Alvin Ding, 2013: 'Oscilloscope for EMI debugging?', EDN Asia. http://www.ednasia.com/ART_8800512114_1000001_TA_651dfdfc.HTM

Dr Markus Herdin, 2014: 'EMI Debugging with the R&S RTO and R&S RTE Oscilloscopes', Application Note 6.2014 - 1TD05 - 1.1e.

Henry W Ott, 2009: 'Electromagnetic Compatibility Engineering', John Wiley & Sons, 1st Edition (11 September 2009), ISBN-13: 978-0470189306.

Clayton R Paul, 2006: 'Introduction to Electromagnetic Compatibility', John Wiley & Sons, 2nd Edition (10 February 2006), ISBN-13: 978-0471755005.

All images by Rohde & Schwarz Gmbh

ASEAN Power Week 2015 to feature presentations by more than 150 international experts

ASEAN Power Week 2015, comprising POWER-GEN Asia 2015, Renewable Energy World Asia 2015, and POWER-GEN Asia Financial Forum 2015, will host more than 150 international experts who will present and discuss the most important topics in the power generation industry, focusing on strategic and technical issues and challenges for the conventional power sector, the continued growth of the renewable and alternative energy sectors, and all aspects of financing for all types of power infrastructure development.

Addressing the theme 'Investing in a Sustainable Tomorrow', the ASEAN Power Week 2015 conference will be a key forum for senior executives, industry leaders and senior engineers to discuss a range of important topics as well as the latest issues and solutions, in order to meet the challenge of the growing demand for electricity in the region.

Organised by PennWell Corporation, the event will be held from 1 to 3 September 2015, at IMPACT Exhibition and Convention Center, Bangkok, Thailand. This year, POWER-GEN Asia will celebrate its 23rd annual gathering.

Dr Praipol Koomsup, Vice Minister of Energy, Thailand, will deliver a Keynote Address to welcome all attendees to ASEAN Power Week 2015.

ASEAN Power Week 2015 has garnered the support and endorsement of the Ministry of Energy, Thailand, as well as the endorsement of Thailand's leading industry-related organisations, including the Electricity Generating Authority of Thailand (EGAT), Thailand Convention and Exhibition Bureau (TCEB), Department of Alternative Energy Development and Efficiency (DEDE), Energy Regulatory Commission (ERC), Provincial Electricity Authority (PEA), Metropolitan Electricity Authority (MEA), Global Power Synergy Company (GPSC), and Thailand Greenhouse Gas Management Organization (TGO). Their support is complemented by the support from top industry bodies including Electrical Engineering Academic Association Thailand (EEAAT) and the Thai Electrical & Mechanical Contractors Association.

"We are extremely excited to be returning to Bangkok this year, as we have always hosted exceptionally successful industry events here. The enthusiasm and support of Thailand's energy industry and authorities are what ensures the success of ASEAN Power Week, and we look forward to setting some new attendance records this September", said Dr Heather Johnstone, Event Director, ASEAN Power Week 2015, PennWell Corporation.

"Moreover, participation of such important organisations and influencers in the power industry and the sharing of ideas and experiences will provide an invaluable insight into future policies, plans and opportunities, which will ultimately help Thailand and the Southeast Asian region better deal with its current and future energy challenges", she added.

More information on ASEAN Power Week 2015 can be obtained from www.aseanpowerweek.com | www.powergenasia.com | www.renewableenergyworld-asia.com | www.powergenasiafinance.com

The audience at the Official Opening of ASEAN Power Week 2014 which was held in Kuala Lumpur, Malaysia.

One of the conference tracks in progress, at last year's event.

Singapore International Energy Week 2015 to focus on 'Global Energy Transitions'

Organised by Singapore's Energy Market Authority (EMA), Singapore International Energy Week 2015 (SIEW 2015) will be held from 26 to 30 October 2015, at the Sands Expo and Convention Centre, Marina Bay Sands, Singapore.

The event will address the theme 'Global Energy Transitions', reflecting how recent volatility in oil prices, growing energy demand in Asia, and increasing market inter-connectivity are greatly re-shaping the global energy landscape. This has prompted re-assessment of long-term investments in both oil and gas, and alternative energy projects. Governments and industry need to consider how to leverage the opportunities and challenges that these developments present. Against this backdrop, SIEW 2015 will address how best to navigate the emerging energy transitions, and the impact these changes would have on the global energy system.

As a prelude to SIEW 2015, EMA hosted a panel discussion with industry leaders. Thomas Jakob, Regional President Asia Pacific, Bosch Software Innovations, Oliver Hsieh, Associate Director, Commodities Price Risk Management, KPMG, and Jonty Rushforth, Editorial Director, Asian and Middle Eastern Oil Markets, Platts, outlined key energy trends for 2015, offering a sneak preview of the discussions that would take place at SIEW this year.

Now in its 8th year, SIEW 2015 will gather top energy thought leaders to participate in the conferences and exhibitions across the entire energy spectrum - including oil and gas, downstream, renewables and energy infrastructure financing.

The week-long programme will build on conversations from SIEW 2014 which saw more than 10,000 delegates from more than 60 countries.

Key focal points of SIEW 2015 will be the SIEW Opening Keynote Address and the Singapore Energy Summit. Together, these provide a platform for high-level dialogue around Asia's new energy frontiers, energy security and energy resilience.

As a special commemoration to mark Singapore's 50th anniversary, SIEW 2015 will host a SG50 jubilee celebration. For the first time, SIEW 2015 will include Gastech, one of the world's largest LNG and natural gas conferences and exhibitions.

Partner events returning for another successful edition include Asian Downstream Week, Asian Energy Financial and Investment Conference, Renewables@SIEW, Asia Clean Energy Summit, and Platt's Annual Top 250 Global Energy Company Awards Dinner.

Singapore International Energy Week

Singapore International Energy Week (SIEW) is a premier platform in Asia for energy insights, partnerships and dialogue, which brings together the world's leading conferences, exhibitions, and roundtables in one week and in one location. SIEW enriches the global energy conversation by convening political, business, academic, and energy industry thought leaders to define and advance the world's leading energy challenges, solutions and actions across the energy spectrum of oil & gas, clean and renewable energy, and energy infrastructure financing. More information can be obtained from www.siew.sg.

Energy Market Authority

The Energy Market Authority (EMA) is a statutory board under the Ministry of Trade and Industry. EMA's main goals are to ensure a reliable and secure energy supply, promote effective competition in the energy market and develop a dynamic energy sector in Singapore. Through its work, EMA seeks to forge a progressive energy landscape for sustained growth. More information can be obtained from www.ema.gov.sg.

Inaugural Critical Infrastructure and Resilience Asia Conference to be held on 25 and 26 June 2015

Mr Pornchai Rujiprapa, Minister of Information and Communication Technology, Thailand, will open the inaugural Critical Infrastructure and Resilience Asia Conference which will be held on 25 and 26 June 2015 at the Avani Atrium Bangkok, Thailand, with an opening keynote presentation.

This important event is co-hosted by Thailand's Department of Disaster Prevention & Mitigation (under the Ministry of Interior), the Ministry of Information & Communication Technology and the Electronic Transactions Development Agency. The event also has confirmed the support of Thailand's Ministry of Transport and the Thailand Convention and Exhibition Bureau, and is sponsored by Thailand's Provincial Electricity Authority.

The event will bring together leading stakeholders from industry, operators, agencies and governments to collaborate on securing Asia. The conference will look at developing existing national or international legal and technical frameworks, integrating good risk management, strategic planning and implementation.

More information can be obtained from www.cip-asia.com.

GE delivers sophisticated electrical conversion system for one of the world's first tidal arrays

This year is turning out to be an exciting one for tidal energy, as one of the world's first tidal arrays near Paimpol-Bréhat, France, will be deployed. Delivering a new generation of renewable energy, the project will harness the predictable power of ocean tides to generate electricity.

Attention is focused on the small French fishing town of Ploubazlanec in Brittany, where development of the tidal demonstrator farm kicked off under the leadership of Electricité de France SA (EDF). GE Power Conversion has been in partnership with EDF since the very beginning and is now on track for finalisation of the electrical conversion system, due for summer 2015. GE's Belfort team is working to perform relevant tests before installing the system both subsea and onshore.

Two OpenHydro 16 m turbines will be connected to a common subsea converter that will transform the current to high voltage direct current (HVDC) to provide 1 MW of electricity. The power will be transmitted to the onshore station and eventually fed into the electrical grid. GE Power Conversion is undertaking development of the subsea converter as well as the onshore station.

The enclosure for the subsea converter is 9 m in length, 5 m in width and 4 m in height. This still small compared to the tidal turbine which measures 16 m in diameter, provided by OpenHydro, part of the DCNS Group.

The converter will be delivered to Brest and be installed by DCNS on the specific foundation designed by OpenHydro, which supports both the converter and the 16 m turbine.

The turbine comprises four key components - a horizontal axis rotor, a direct-drive permanent magnet generator, a hydrodynamic duct and a subsea gravity base foundation. Simplicity is a key advantage of the device, with no lubricants, seals or gearbox, resulting in reduced maintenance requirements.

The turbines with the converter are placed directly onto the seabed, deep enough so as not to pose a hazard to shipping.

Among the advanced technology employed to put the complex electrical design into action is GE's MV3000 low voltage drive. Together with other electrical components, it enables the low voltage alternating current, generated by the open-centre turbines to be transformed into HVDC. The electrical current will then be transported through the 16 km subsea cable to the onshore station. HVDC reduces significantly energy loss and therefore offers remarkable energy savings over long distance power transmission.

Being among the first projects of its kind, it was up to GE Power Conversion to conceptualise, assemble and test the highly advanced subsea converter, drawing from a wealth of expertise in marine and subsea projects.

"Reliability is of the utmost importance in this project. Once the equipment is installed on the seabed, it has to run in full autonomy for a minimum of five years duration. We have full confidence in GE Power Conversion to design and build a reliable and robust system that will allow continuous power generation and other operation requirements", said Régis Baudet, Project Manager, EDF.

The MV7000, once installed in the onshore substation, converts HVDC back to HVAC which is compatible with the French grid.

"GE Power Conversion's advanced engineering coupled with customised solution brings optimised power conversion efficiency. While 1 MW power output transmitted over 16 km distance seems modest, GE's engineering design for this project sets the foundation for future applications with higher power and longer distance transmission", said Frédéric Navarro, Project Director, GE Power Conversion.

Furthermore, GE's subsea converter also has the potential for future upgrades, as its design leaves the possibility of connecting with two additional turbines.

"As one of the first tidal farms of its kind to soon start operation, it is a big step forward for GE to position itself in the growing tidal market. Bringing its robust and innovative products and systems built on proven technology, GE is committed to unlocking the huge potential of tidal energy to power the world", said John Chatwin, Power & Industry Segment Leader, GE Power Conversion.

GE Power Conversion

GE's Power Conversion business applies the science and systems of power conversion to help drive the electrification of energy infrastructure by designing and delivering advanced motor, drive and control technologies that evolve today's industrial processes for a cleaner, more productive future. Serving specialised sectors such as energy, marine, oil and gas, renewables and industry, through customised solutions and advanced technologies, GE Power Conversion partners with customers to maximise efficiency.

GE's electrical conversion system will transform the current to high voltage direct current (HVDC).

ABB, Bosch and Cisco establish open-software venture to unify smart home technology

ABB, Robert Bosch GmbH and Cisco Systems Inc recently confirmed the formation of an international joint venture called mozaiq operations GmbH to develop and operate an open-software platform for smart homes. The platform will help to unify today's stand-alone solutions for home automation and offer interoperability across devices.

The platform, to be developed by mozaiq operations GmbH, brings the Internet of Things, Services and People into consumers' homes, making it easy and secure for a wide range of products to communicate with one another.

Consumers will be able to seamlessly and intuitively tailor their appliances and devices, regardless of brand, to deliver an unprecedented level of control, comfort and significantly improve energy efficiency. For example, on an unexpectedly hot day, either through a click from a smart phone or through a pre-set instruction, blinds in the home can be closed, the preset timer for the tumble drier could be switched off, and all screen devices automatically switched off for the children to go outside to play.

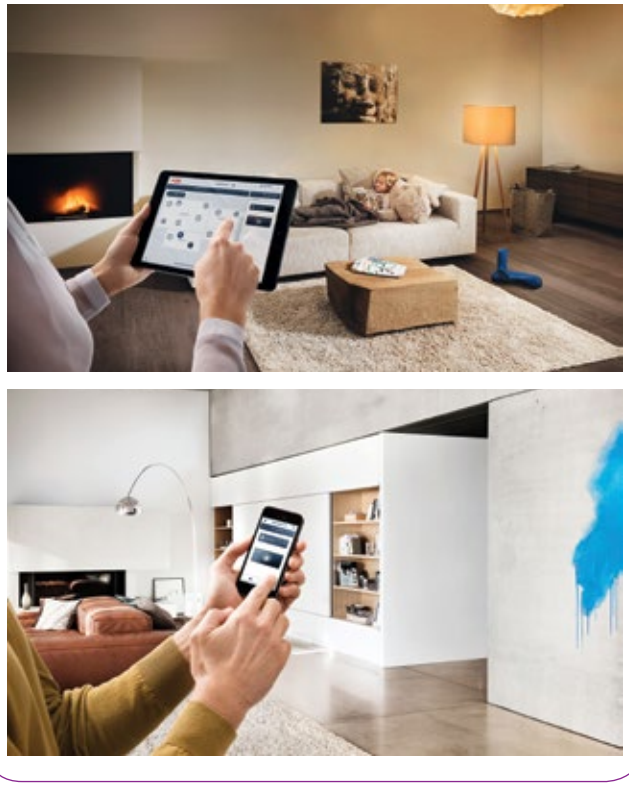
"This joint effort to develop an open-software platform for smart homes fits perfectly with ABB's strategy to leverage the expanding opportunities of the Internet of Things, Services and People for consumers and companies alike", said Mr Tarak Mehta, Head of ABB's Low Voltage Products Division.

"ABB has a comprehensive range of solutions for residential and commercial buildings and is committed to driving innovation in this exciting space. Collaborations such as mozaiq will ensure that consumers have faster access to the best-possible technology", he added.

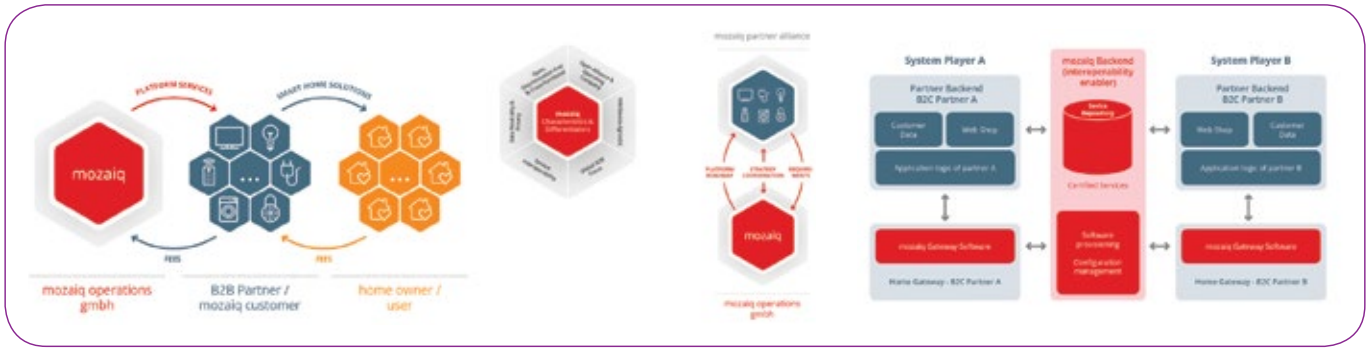
The mozaiq software platform will create opportunities for a range of new services by facilitating the simple, but secure exchange of data between different types of devices and their users. By creating a business ecosystem, ABB, Bosch and Cisco seek to facilitate cooperation and accommodate stakeholders' varying demands and perspectives as the software platform is developed.

The interim head of mozaiq will be Dirk Schlesinger of Cisco Internet Business Solutions Group. He will be based in Frankfurt, Germany, until a permanent leader is appointed.

An innovative website has been created to provide more details regarding the open software platform and create a hub for customers of the joint venture, at http://mozaiq-operations.com.



The platform, to be developed by mozaiq operations GmbH, will enable consumers to seamlessly and intuitively tailor their appliances and devices to deliver an unprecedented level of control, comfort and significantly improve energy efficiency.



The mozaiq software platform will create opportunities for a range of new services by facilitating the simple, but secure exchange of data between different types of devices and their users.

Singapore Power and EDB establish Centre of Excellence

Singapore Power (SP) recently launched the Singapore Power Centre of Excellence for Energy Development and Piloting at an initial investment of S$ 30 million. The Centre of Excellence (CoE) will drive the innovation and commercialisation of next-generation energy network technologies, for greater reliability and efficiency of Singapore's infrastructure.

The CoE, supported by the Singapore Economic Development Board (EDB), will develop, pilot, and integrate cutting-edge technologies in Singapore's infrastructure networks. For example, remote sensors and intelligent drones could be deployed to perform monitoring tasks, freeing up skilled staff for higher order work.

SP will form a dedicated 20-man team to spearhead the CoE. This core group will develop expertise in the development, testing and integration of new technologies in Singapore.

The CoE will test-bed these technologies to validate technical viability, integrate them with SP's networks, and eventually commercialise them. This will also support SP's objective to build future-ready networks and capabilities, to deal with the global trends such as the drive for smarter and greener performance, as well as the adoption of renewable sources.

"Our energy networks are the backbone of our economy and standard of living. The SP CoE will provide the platform for testing, developing and implementing innovative solutions. These made-in-Singapore innovations will be key to our goal to be the first smart energy network in Asia, in turn enhancing our ability to continue serving our customers efficiently and reliably. We hope the establishment of the CoE marks the beginning of a strong and fruitful partnership with EDB. We also look forward to collaborating with industry partners to develop the next generation energy solutions", said Mr Wong Kim Yin, Group CEO, Singapore Power.

"Through the Centre of Excellence, Singapore Power will work with leading industry players in Singapore to develop and test solutions across the value chain. With strong technology expertise and the presence of many top companies in the power equipment and energy management space, we believe that Singapore is an ideal place for these collaborations to take place. We look forward to innovative solutions being co-developed between SP and its industry partners, thereby allowing Singapore to reap the benefits of an enhanced grid network, as well as to contribute to smart grid development in Asia", said Mr Yeoh Keat Chuan, Managing Director, EDB.

In conjunction with the launch of the CoE, SP also announced the Singapore Power Energy Advanced Research and Development (SPEAR) programme as the CoE's first initiative. Examples of technologies to be explored under SPEAR are in the areas of instrumentation and control, grid communications and smart energy management.

SP is currently calling for industry companies to participate in SPEAR. Projects will be selected via a competitive and merit-based process, with awards expected from the fourth quarter of 2015 onwards. More details on SPEAR can be obtained by emailing COE@singaporepower.com.sg.

THEMES FOR SPEAR

SPEAR will see SP partnering industry companies to develop and pilot next-generation technologies that would enhance Singapore's electricity value chain. The themes for SPEAR are:

- Next-gen SCADA: System with standardised communication protocols and algorithms to effectively manage and integrate energy flow of the future grid.
- Next-gen grid communications: Hybrid network (wireless and wired) with high availability, which is sustainable and scalable for increasing smart grid applications.
- Grid sensing: Real-time synchronised system to address a more dynamic distribution network switching environment and growing penetration of intermittent non-dispatchable renewables.
- Substation modernisation: Non-proprietary, open-protocol solution that integrates all types of intelligent electronic devices.
- Advanced condition monitoring technologies.
- Turnkey tagging technologies for underground assets.
- Infrastructure and capabilities development to enable customer segmentation to improve energy demand-side applications and offer value-added services.

A peek into the future

The technologies developed under the CoE will ensure Singapore's electricity networks are capable of handling the changing demands on it, both in the near-term as well as in the future.

Below is an example of what could result from innovations in advanced condition monitoring technologies and turnkey tagging technologies for underground assets.

Today, SP is constructing two electricity transmission cable tunnels, 60 m underground. When completed, the 18.5 km North-South and 16.5 km East-West tunnels will provide secure corridors for faster and more efficient transmission cable installation.

Both in Singapore as well as elsewhere in an urbanising world, building large infrastructure projects underground will become increasingly common to optimise land use.

However, burying large numbers of cables and other equipment deep underground presents a unique challenge - how does one ensure they are working properly if one cannot easily check on it physically? The answer lies in turnkey tagging technology. Every piece of equipment, down to individual cables, will have a unique tag allowing real-time identification and monitoring of health, operating status and location.

These tags would be designed for underground conditions, being abrasion-resistant and impervious to water and environmental chemicals. They would be durable, lasting at least 30 years. Finally, they would be future-ready, being interoperable with all monitoring systems.

SINGAPORE POWER

Singapore Power Group is a leading energy utility group in the Asia Pacific region. It owns and operates electricity and gas transmission and distribution businesses in Singapore and Australia.

Mr Wong Kim Yin, Group CEO, Singapore Power(left) presents a token of appreciation to Mr Yeoh Keat Chuan, Managing Director, EDB, at the launch of the Singapore Power Centre of Excellence for Energy Development and Piloting.

More than 1.4 million industrial, commercial and residential customers in Singapore benefit from SP's world-class transmission, distribution and market support services. The networks in Singapore are amongst the most reliable and cost-effective worldwide.

World Energy Council welcomes DNV GL as new Global Partner

The World Energy Council has welcomed DNV GL, a major global resource of independent energy experts and a leading technical advisor to the global oil and gas industry, as the newest member of its Global Partner programme.

DNV GL delivers testing, certification and advisory services to the energy value chain, including on renewables and energy efficiency. Its expertise spans onshore and offshore wind power, solar, conventional generation, transmission and distribution, smart grids, sustainable energy use, as well as energy markets and regulations. For the oil and gas industry DNV GL provides a broad range of services, such as technical assurance, marine assurance and advisory, risk management and offshore classification.

"DNV GL's overall goal is to help governments, energy providers and other stakeholders manage the world's growing demand for energy, while balancing costs, reliability and the environment. In this energy trilemma, we take a broader view of working beyond borders and boundaries, sharing our expertise from various regions and transferring these best practices to where they can achieve the most. I look forward to work with the World Energy Council and their network to learn and share our expertise as we strive for safety and sustainability in the energy and oil & gas industry", said Mr David Walker, CEO of DNV GL-Energy.

As a Global Partner of the Council, DNV GL will also be actively engaged in the activities of its national member committees in the Netherlands, Norway, South Africa and the US to promote sustainable energy development in these countries as a part of the World Energy Council's energy vision.

"Our Global Partners provide important insights for our dialogues in today's uncertain energy world. DNV GL has significant experience in standardisation, certification and risk assessment across the entire energy value chain and with worldwide reach. Its insights at a time of important innovation will be greatly valued by our exclusive global energy leadership community", said Mr Christoph Frei, Secretary General of the World Energy Council.

Phoenix Solar to build 1.96 MWp of rooftop PV for LTA

The Land Transport Authority of Singapore (LTA) has awarded a contract to Phoenix Solar Pte Ltd, (Phoenix Solar) for the construction of 1.96 MWp of rooftop PV systems at the Tuas and Gali Batu train depots in Singapore.

LTA is responsible for the planning and development of Singapore's land transport infrastructure. Achieving cleaner and greener transport is one of its priorities, as well as reducing the environmental impact of its business activities. Generating clean electricity for train depot operations is a significant step in this direction.

In August 2014, LTA called for a competitive tender to design, supply and install 1.96 MWp of grid-tie PV capacity at two new train depots - in Tuas and Gali Batu. Train depots offer several advantages when installing PV, as they are typically located in areas with no surrounding tall buildings. The roofs at depot workshop / stabling buildings are large and usually clear of equipment, so solar panels need not compete for space against other facilities such as water tanks.

The project was awarded to Phoenix Solar after evaluating tenderers based on the quality of their proposals as well as pricing.

Upon completion, the PV systems, comprising 7,536 REC solar modules and four central inverters from SMA, are expected to generate over 2.2 million kWh of solar electricity annually. This is enough to mitigate over 1,100 metric tonnes per year of CO_2 from gas-fired power plants, based on typical emissions of 0.5 tonnes of CO_2 / MWh.

Phoenix Solar will also maintain and monitor the performance of the PV systems over an initial period of one year.

This project dovetails nicely with the Singapore Government's plans to expand its promotion of renewable energy such as PV energy to power public sector projects.

Singapore has enough space to accommodate 6 GWp of solar PV, which can generate 7.5 TWh of electricity each year, or approximately 17% of Singapore's current electricity demand. The figure 6 GWp is based on the installation of 100Wp/m², assuming accessible space on rooftops, LRT tracks and reservoirs.

"Looking ahead, we expect PV to cover more industrial factories, depots, warehouses, schools and government facilities", said Mr Christophe Inglin, Managing Director of Phoenix Solar.

"The installations will not only provide environmental benefits but also commercial returns, as PV today is a commercially viable complement to conventional energy in Singapore", he added.

With the addition of the PV systems for LTA, Phoenix Solar boasts eight rooftop installations in the MW range, in Southeast Asia, bringing its rooftop portfolio, which includes many award-winning projects, to over 19 MWp.

Philips appoints two senior leaders for its lighting business

Mr Murali Sivaraman

Philips has announced the appointment of Mr Murali Sivaraman as President of Growth Markets for Lighting, and Ms Patricia Yim as President of Lighting for ASEAN Pacific. Both Mr Sivaraman and Ms Yim will be based in Singapore.

Ms Patricia Yim

In his new global role, Mr Sivaraman will have responsibility for the company's lighting business in Asia Pacific, India, Japan, Middle East, Turkey and Russia. He has been with Philips since 2007, first as General Manager for Philips India and more recently as part of the Consumer Lifestyle business.

Ms Yim brings with her almost 30 years of IT industry experience at IBM, where she most recently ran its Global Technology Service in Greater China. Her focus markets are Southeast Asia, Australia, New Zealand, Pakistan, and South Korea.

Last year, Royal Philips announced the creation of two market-leading companies focused on HealthTech and Lighting Solutions opportunities. The Lighting Solutions business is already the global leader in lighting and serves a growing market estimated to exceed €60 billion.

ADVERTISERS' INDEX

BENTLEY SYSTEMS INTERNATIONAL LIMITED — PAGE 15

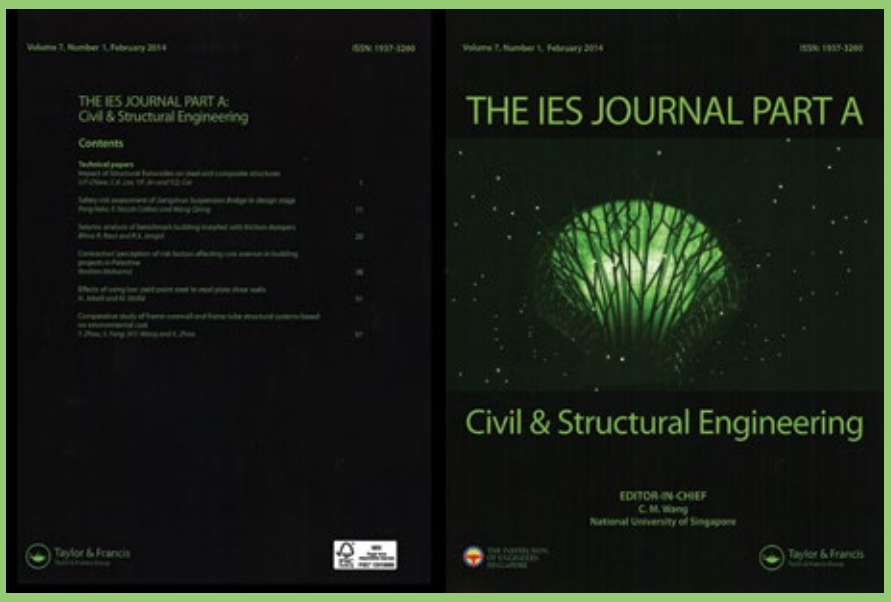
LAND TRANSPORT AUTHORITY — PAGE 17

LUMA GROUP LIGHTING — OUTSIDE BACK COVER

PENNWELL CORPORATION — INSIDE FRONT COVER

WES 2015 — PAGE 7

The IES Journal Part A: Civil & Structural Engineering Vol. 8 is finally available with new cover design! Members exclusive rates: SG$100/yr (U.P. US$295)



Now indexed by **SCOPUS** and **Compendex**, the IES Journal is written by world renowned researchers and practitioners. The Journal provides a forum for the dissemination of original research and developments in civil & structural engineering.

The papers cover a wide range of engineering issues in structural, geotechnical, water resources, environmental and infrastructural fields, and offer a focused, vibrant and timely communication tool for researchers, consultants and industry practitioners.

Subscribe to the IES Journal Part A: Civil and Structural Engineering Vol.8 at an exclusive rate of SG$100/yr (U.P. US$295) for IES members only.

The 2015 volume of the IES Journal Part A is published on a quarterly basis. Visit the publisher's website at http://www.tandf.co.uk/journals/tiea for more information as well as a sample copy.

For further enquiries, please call Rebekah Yeo
at 64695000 or email rebekah.yeo@iesnet.org.sg

Self-reading of this journal by PEs may be used to apply for PDU (unstructured) points.

This is the world 's smallest light bulb and it generates 45,000 lumens per source, and works well with intelligent controls for dimming, on-offs and remote access. It triples the life of HID, yet consumes 50% less energy. They last an average of 10 years, giving you not just brilliant lighting but also durability. For the last 20 years, Luma Group Lighting has been pioneering the development and application of electrode-less long-life light sources. Call us at 68469063 today for a consultation.

www.lumainvestments.com

LUMA